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The iron ores of Great Britain.

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MEMOIRS

OF THE

GEOLOGICAL SURVEY

OF

GREAT BRITAIN,

AND OF THE

MUSEUM OF PRACTICAL GEOLOGY.

THE IRON ORES OF GREAT BRITAIN.

Parts I–IV.

PART I.

THE IRON ORES OF THE NORTH AND NORTH-MIDLAND COUNTIES OF ENGLAND.

PUBLISHED BY ORDER OF THE LORDS COMMISSIONERS OF HER MAJESTY'S TREASURY.

LONDON:

PRINTED FOR HER MAJESTY'S STATIONERY OFFICE.

PUBLISHED BY

LONGMAN, BROWN, GREEN, AND LONGMANS.

1856.

In the annual Parliamentary Report of this year upon the Progress of the Geological Survey of the United Kingdom and this Establishment, I have already spoken of the inquiry into the composition of British iron ores as being of great national importance. I feel confident that this First Part of the Memoir on that subject, containing some of the analyses carried on in our metallurgical laboratory, under the able guidance of Dr. Percy, will satisfy the public as to one of the obvious uses of this School of Mines. The clear and accurate description, by our mining geologist, Mr. Warington Smyth, of the various rock formations in which the ores occur, forms a valuable portion of the Memoir.

RODERICK I. MURCHISON,
Director.

Museum of Practical Geology,
Jermyn Street, May 23, 1856.

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PREFACE.

In the Great Exhibition of 1851 there appeared a very extensive series of the iron ores of the United Kingdom, which were collected, arranged, and catalogued by Mr. Blackwell, of Dudley. To the ordinary spectator there could be nothing less attractive than that collection, although it truly represented one great element of the wealth, the power, and the prosperity of the country.

At the close of the Exhibition Mr. Blackwell generously presented the collection, upon the formation of which he had expended a considerable sum, to the Museum of Practical Geology, in order that it might permanently be preserved in a national institution, and be constantly accessible for inspection. But this is not all. Mr. Blackwell, conceiving that the practical utility of the collection would be greatly increased by the knowledge of the exact composition of the ores, munificently offered to place at the disposal of the lecturer on metallurgy the sum of 500*l.* towards defraying the expenses of an analytical investigation of all the more important varieties of ore in the collection. The offer was accepted, and the results are presented in this volume. The investigation has been conducted in the metallurgical laboratory of the School of Mines; and although it was commenced in February 1852, it is not yet quite completed. It should also be stated that Mr. Blackwell

expressly stipulated that the results should be published; for notwithstanding he is himself extensively engaged in the smelting and manufacture of iron, he yet entertained no narrow-minded notion of exclusive personal advantage, and was willing that others should partake of any benefit which the knowledge resulting from such an investigation might confer.

Almost all the analyses have been conducted by Mr. Allan B. Dick and Mr. John Spiller, a few only having been made by Mr. Edward Riley, who received an appointment at the Dowlais Ironworks shortly after he had entered upon the investigation. The labour, as every chemist will observe on inspecting the recorded results, has been very great; and it required no small amount of enthusiasm and perseverance on the part of an analyst to devote himself continuously to the same kind of work during so long a period. As it is right that every man should receive the entire merit of his own labours, the names of the gentlemen above mentioned will be attached to their respective analyses.

There is no metallurgical problem of greater practical importance than the determination of the causes which occasion the differences in quality of the various kinds of iron, differences which have long been recognized by engineers familiar with the use of iron in the construction of bridges, buildings, and railways. Now it is certain that, exclusive of effects due to mechanical treatment, these differences in quality are of a chemical nature. It must be borne in mind, that chemically pure iron is known only as a curiosity even in a laboratory; and that all the substances to which the term iron is commonly applied are compounds, and frequently very complex compounds. But differences

of chemical constitution in iron must depend upon differences of chemical constitution either in the ores, the fuel, or other materials used in smelting, or upon differences in the mode of conducting the process of smelting. It has been demonstrated that all these causes, either separately or conjointly, may be powerfully operative in determining the quality of iron; and it may be asserted that not the least influential are those which relate to the ores and fuel. It is hoped, therefore, that, so far as relates to the influence due to the ores, the present investigation will furnish decisive results of considerable practical importance.

Mr. Kenyon Blackwell, elder brother of Mr. Blackwell, who has had considerable experience in the smelting and manufacture of iron, and who has had the opportunity of acquiring a practical knowledge of the character of the British iron ores, undertook the selection and sampling of the ores for analysis. In every case, as far as practicable, a fair average sample of ore was taken; and as respects those varieties of ore which, occurring in contiguous measures, are gotten together in the mine, and which also are smelted together, the sample was prepared for analysis by triturating together an equal weight of each particular variety. Thus, for example, when reference is made in Analysis No. VIII. to the Nos. 305 to 310, it signifies that the specimen subjected to analysis was prepared by triturating the same weight of the ores from No. 305 to No. 310 inclusive.

It must be borne in mind, that in some varieties of iron ore certain substances may occur only occasionally, very irregularly diffused, as, for example, Millerite (sulphide of nickel) in the ore near Merthyr, or blende, galena, and copper pyrites in several of the Staffordshire ores. It is, therefore, probable that, notwithstanding the care bestowed

in the selection of the samples, such occasional substances may yet have been absent in the specimens subjected to analysis.

In some cases it has been necessary to apply for additional specimens of ores in order to obtain as characteristic an average sample as possible, and we have pleasure in recording the promptness with which such applications have in general been attended to; but we are compelled to state that in other cases similar applications have been made in vain to more than one firm in Staffordshire, not from any disinclination, we suppose, to furnish them, but, as it would appear, from mere dilatoriness, and want of appreciation of the necessity of more accurate knowledge.

After all, it must be acknowledged that the value of an analytical investigation of iron ores would be very much increased by a corresponding investigation respecting the iron produced and the fuel and flux employed in the process of smelting. Such a work would require great skill and persevering labour, but would be certain to yield results of great practical value and high scientific interest.

Researches of a similar kind, with reference to the materials employed in the manufacture of cannon, have been during several years conducted by the officers of the Ordnance Department of the United States, and a handsome quarto volume of the results has been published by the United States Government in the present year.* It is proposed to carry out a more extensive series of analyses,

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* Reports of Experiments on the Strength and other Properties of Metals for Cannon. 4to, 1856.

" conjoined with exact mechanical tests;" and the officers engaged in this labour at Pikesville Arsenal truly observe, in summing up their Report, " The strongest argument in " favour of such an investigation is its own importance and " prospective advantages; for the manufacture of iron is " the basis and index of modern civilization, and every " effort tending to improve it is a matter of general " welfare."

JOHN PERCY, M.D., F.R.S.

Metallurgical Laboratory,
Museum of Practical Geology,
London, May 1856.

Iron Ores of the Northern and North-midland Counties of England (Cumberland, Durham, Northumberland, Lancashire, Yorkshire, and Derbyshire).

General Description. (By W. W. Smyth, M.A.)

In no part of the world has the production of iron advanced with more rapid steps than in the north of England, nor is there perhaps a limited district where the ores and their resulting irons are more varied in character; and although some of the mines to be noticed in this paper have been long celebrated for the part they have taken in contributing to this important branch of British manufacture, others of them have sprung into existence, and attained to colossal dimensions, within a period so recent as to invest them with a peculiar interest.

The employment of the ironstone which occurs in the coal measures, has from very early times invited the establishment of iron furnaces in the coal field of Derbyshire and the south-western part of Yorkshire, and these works are most of them honorably distinguished for the good quality of the material which they produce. Farther north there existed in the neighbourhood of Newcastle, in the year 1828, but one iron work, consisting of two blast furnaces; whereas within the last few years the improved means of transit and the increasing demand for iron have created extensive establishments, situate chiefly on the western border of the coal field, and fed with ores from various and distant localities. More recently still, within half a dozen years, the discovery and application of the abundant stratified ores of the Cleveland district in Yorkshire, has led to the erection of groups of smelting works in the southern part of Durham, and near Middlesbro' in Yorkshire; and whilst in some cases the ore is conveyed for many miles by railway to the coal producing district, in others the fuel is transported in the opposite direction to the immediate neighbourhood of the iron mines.

It is proposed in the following pages to give a brief account of the mode of occurrence of the ores of iron which are chiefly employed in these districts; and it may be useful in the first place to impress upon the reader the very high importance of these establishments in the North of England, by setting before him a summary of the blast furnaces now in operation.

Name of Works.	Owners.	No. of Furnaces.	Furnaces in blast.
	NORTHUMBERLAND AND DURHAM.		
Auckland - -	- - - - -	4*	
Bedlington - -	Bedlington Iron Co. -	2	2
Birtley - -	Birtley Iron Co. -	3	3
Clarence - - -	Bell, Brothers - -	3	3
Consett - - } Crookhall - - }	Derwent Iron Co. -	14	14
Darlington - -	H. Pease and Co. -	2	2
Felling - - -	Pattinson and Co. -	2	2
Hareshaw - -	Hareshaw Iron Co. -	3	
Hartlepool, near -	- - - - -	2*	
Lemington - -	Tyne Iron Co. - -	2	2
Stanhope - - } Tow Law - - }	Weardale Iron Co. -	{ 1 6	4
Stockton - -	Stockton Iron Co. -	3	3
Shotley Bridge or Bradley	Richardson and Co. -	4	4
Walker - - -	Losh, Wilson, and Bell -	5	4
Wallsend - -	Carr and Co. - -	2	2
Witton Park and Etherley	Bolckow and Vaughan -	4	4
Wylam - - -	Bell, Brothers - -	1	1
	YORKSHIRE.		
	Cleveland District.		
Cleveland - -	Elwin and Co. - -	3	2
Eston - - -	Bolckow and Vaughan -	6	6
Middlesbro' - -	Ditto - - - -	3	3
Ormesby - -	Cochrane and Co. -	4	3
South Bank - -	Samuelson and Co. -	3	3
Tees - - -	Gilkes, Wilson, and Co. -	4	4

* Now building, January 1856.

Name of Works.	Owners.	No. of Furnaces.	Furnaces in blast.
	YORKSHIRE—*continued.*		
	Coal Measure District.		
Beeston Manor - -	Harding and Co. - -	1	1
Bierley - -	Hird, Dawson, and Hardy	4	3
Bowling - - -	Sturge and Co. - -	5	4
Chapeltown - -	Newton, Chambers, and Co.	2	1
Elsecar - - -	Dawes and Co. - -	3	1
Farnley - -	Armitage and Co. -	2	2
Holmes - - -	S. Beale and Co. - -	2	2
Low Moor - -	Hird, Dawson, and Hardy	5	4
Milton - - -	Dawes and Co. - -	2	2
Parkgate - -	S. Beale and Co. - -	1	1
Thorncliffe - -	Newton, Chambers, and Co.	3	2
Thorpe Hall - -	J. and H. Haines - -	1	1
Wosbro' Dale - -	Field, Cooper, and Co. -	1	1
	DERBYSHIRE.		
Alfreton - -	Oakes and Co. - -	3	2
Brimington - -	Knowles and Co. -	1	1
Butterley - -	Butterley Company -	3	3
Codnor Park - -	Butterley Company -	4	4
Duckmanton - -	R. Arkwright - -	2	
Clay Cross - -	Clay Cross Co. - -	3	2
Morley Park - -	Mold and Co. - -	2	2
Newbold - -	S. Beale and Co. -	1	1
Renishaw - -	Appleby and Co. -	2	1
Stanton by Dale -	Stanton Iron Co. -	3	3
Staveley - -	Rd. Barrow - -	4	2
Unstone - - -	Rangeley and Co. -	1	1
West Hallam - -	Whitehouse and Co. -	3	2
Wingerworth - -	Wingerworth Iron Co. -	3	3
	CUMBERLAND.		
Cleator - -	Whitehaven Iron Co. -	3	2
	LANCASHIRE.		
Newland - - / Backbarrow - - / Duddon - -	Harrison, Ainslie, and Co.	3	1

SUMMARY.

	No. of Furnaces.	Furnaces in blast.
Northumberland and Durham - - -	63	50
Yorkshire - - - - - -	55	46
Derbyshire - - - - - -	34	26
Cumberland - - - - -	3	2
Lancashire - - - - - -	3	1
Total - - -	158	125

These smelting furnaces alone, irrespective of the mines, mills, and forges with which they are connected, represent, in mere erections and plant, a sum of half a million sterling.

The ores of iron raised in the northern counties, belong, geologically speaking, to three different formations, viz.

1. *The Carboniferous Limestone;* Weardale, Alston Moor, Haydonbridge, Whitehaven and Ulverstone.

2. *The Coal Measures;* Western edge of coal fields of the Tyne and Wear; coal fields of Yorkshire and Derbyshire.

3. *The Lias;* Cleveland district, in the north-east of Yorkshire.

The greater part of the blast furnaces employ, according to the facilities afforded by their position, ores derived from various localities; and it is therefore desirable, in discussing the materials from which iron is made in the establishments above enumerated, to group together the various ores under the divisions most naturally afforded us by the classification of the several rock formations.

Ores of the Carboniferous Limestone.

Analyses have been completed of the following—

	Catalogue of 1851.	Analyses, page
1. Weardale Ores, Tow Law Iron Works -	—	55
2. Carbonate of Iron, Rispey, Tow Law Works	—	58
3. Hæmatite, Cleator, Whitehaven - -	424,426	60
4. do. do. - - -	427,429	61
5. do. Gillbrow Ore, Ulverstone, Lancashire.	—	63
6. Hæmatite, Lindale Moor, Ulverstone -	—	65

The principal mass of the carboniferous or mountain limestone* of the iron-producing districts under consideration, emerges from beneath the coal measures of Durham and Northumberland on the east, and is bounded by a steep declivity overlooking the vale of Eden on the west. It reaches a culminating point in the long mountain ridge of Cross Fell, and forms the vast tract of moorland, which near Alston extends for some 25 miles in width, and in the high desolate region adjoining the Scotch border, stretches across almost from sea to sea.

After an interval of some miles towards the west, the same formation rises again from beneath the new red sandstone of Penrith and the coal measures of Workington and Whitehaven, and lapping as a narrow belt round the older slaty rocks of the lake district, almost entirely encircles this the most beautiful region of England.

The structure of the central high land first mentioned, in which are situated the towns of Alston, Hexham, and Haltwhistle, differs materially from the contemporaneous formation which occurs farther south in England and Wales, and which consists principally of uninterrupted beds of limestone

* For a detailed account of the structure of this important formation, see Westgarth Forster's Section of the Strata, 1821, and Phillips's Geology of Yorkshire.

to a vast thickness. In the north the actual limestone plays but a subordinate part, and alternates with strata of grit-stone and shale, locally termed "hazle" and "plate." Certain ores of iron are interstratified with these beds; nodules of clay ironstone, the argillaceous carbonate, are met with in some of the bands of shale, the mode of aggregation being analogous to that of the similar ores of the coal measures. At Hareshaw, near Bellingham, towards the source of the North Tyne, four furnaces were erected some years ago, to smelt the clay ironstones which were obtained from the series of "sills" or beds intervening between the so-called "great limestone" of the Alston District, and the "second" or "little limestone" which lies about 60 feet above it. They produced excellent iron, but the expensive cartage of the ore, and the absence of railway or canal communication, were fatal for the time to the success of the establishment.

Near Haltwhistle and Nenthead the same "ballstones" have been worked at their outcrop.

Masses of brown iron ore (the hydrous sesquioxide of iron) appear in some instances to form regular layers, although their presence is probably in close relation to the veins of metallic minerals which in great numbers intersect the rocks in and around Alston Moor.

It is not until farther and systematic workings shall have been followed out that the true nature and extent of these apparent strata can be determined.

A bed of the carbonaceous iron ore termed "black band" was discovered a few years ago and worked till within a recent period, about one and a half miles north-west of Haydon-bridge, near the Newcastle and Carlisle Railway; it ranged from two and a half to three feet in thickness, and being calcined on the spot, was proved at the Shotley Bridge furnaces to be a very valuable ore, but its cropping out on the west, and disturbances of the ground on the east, limited its exploration. Its true position in the series of the measures

is not rightly understood, although it underlies a thick band of limestone, which may lead to the identification of its place; and it appears not improbable that a closer geological investigation of the neighbourhood might prove the existence over a larger area of this important substance.

The majority of the mineral veins or lodes of the Alston district, celebrated for their productiveness of lead ore, range nearly from east to west, intersecting the whole of the above-mentioned beds, but yielding their riches far more abundantly in certain strata than in others. Some of these lead veins, in a part of their course, are charged with brown iron ore instead of the usual veinstone of fluor spar and quartz and its concomitant lead ore. Thus the rich lode of Rodderup Fell where it crosses the valley of the Tyne, above Alston and is known as the Craig Green or Bracken Syke vein, is seen in the so-called "scar" limestone, as a vein of brown iron ore from 16 to 20 feet in width. Hitherto, however, from the remote position of the district, these repositories of an ore so well calculated to produce a good quality of iron have been very little explored.

Since the late extension of a branch railway to the town of Alston certain of the lodes, apparently producing nothing but this kind of ore, have been extensively wrought. Thus the Manor House vein has been opened very near the railway station, for the Shotley Bridge Company, and hundreds of tons have been raised from a very small area at the extremely low cost of 1*s.* 7*d.* per ton.* The vein is about 14 feet wide striking east and west, with a northerly dip, and throwing down the measures on its north wall about 12 feet. Its productiveness is increased by tongues or "flats" which penetrate to the distance of a few feet between the layers of the scar limestone which it here intersects.

* It is worthy of note, that here, as in so many other localities, our forefathers had availed themselves of the occurrence of a rich ore to work it for their small charcoal furnaces; on the late opening of these works, remains of ancient galleries and a horse shoe were found, although the existence of old workings was not betrayed by any surface appearances.

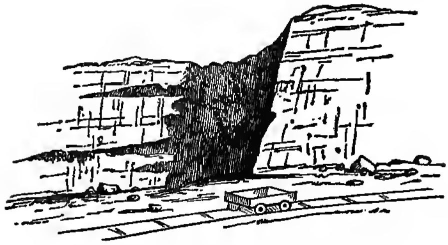


Diagram Section of Manor House Lode.

On the opposite side of the valley of the Tyne, the Park or Horse Edge vein has also lately been wrought, and considerable quantities of a similar brown ore are now being raised from the Thorngill vein where it intersects the "great" limestone.

To the west, on the northern shoulder of Cross Fell, and to the east at Kilhope, and in Weardale, the outcrops of similar iron veins present themselves. Crusts of manganesian botryoidal peroxide occur abundantly near the surface, varied by the delicate reddish brown tint of lepidokrokite. At the former locality some of the corals characteristic of this formation are found enveloped in and entirely fossilized in brown iron ore, a curious series of changes having probably operated on the fossiliferous limestone which at one time formed the walls or sides of the vein.*

In the eastern part of this region, another, the "sparry" ore, or carbonate of iron, makes its appearance abundantly in the lead veins, and is locally termed the "rider" or veinstone accompanying the ore which has been the chief object of search. At the mines of Allenheads, belonging to Mr. Beaumont, M.P., the sparry iron ore occurs both in the regular lodes and in the "flats" which insinuate themselves from them laterally into the limestone. Adjoining Weardale this character is still more pronounced, and in the neighbourhood of Stanhope burn the veins are so "ridered," so charged with this ore, that at a spot where several of them occur in close proximity, and interlacing "strings" additionally enrich

* See specimens in the Museum of Practical Geology, wall case 49.

the ground, the whole surface has been removed from a large area by the Weardale Iron Company, and the rock absolutely quarried away, a considerable amount of lead ore being separated during the operation.

The ore No. 2, of which the analysis will be given, is derived from the Rispey vein in Rookhope, a lateral valley opening into Weardale. Here, as elsewhere in the district, brown peroxide is often mingled with the sparry ore, especially near the surface, where it sometimes spreads over a width of 30, 40, or more feet. There is little doubt that the brown ore is due to the decomposition effected by atmospheric or *anogenic* action, and that it was all originally placed *in situ* in the condition of a carbonate.

Remembering the high character of the iron which is produced from similar ores on the continent, more especially the celebrated "steel irons" of Siegen, and Styria, and Carinthia, it will be seen that the introduction of this ore into the British iron manufacture is a step of importance. Nor should it be forgotten, that till very recently it has been regarded as mere refuse during the working of the lead veins, and that larger quantities of it may reward farther research through these extensive moorlands.

Mr. Charles Attwood of the Tow Law works, to whom is chiefly due the merit of testing the value of the sparry ores, states that he employs much less of it than he could wish, in consequence of the comparatively scanty population, and of the greater expense of *getting* as compared with the brown ore, and that he reserves it for making the very best and highest priced irons.

When we look to the successive introduction of the various minerals which have filled these interesting veins, it is evident that the carbonate of iron has been one of the latest comers. Many of the specimens exhibit it investing as a crystalline incrustation the previously formed crystals of fluor spar and galena, and the striking manner in which it is often found to coat only those surfaces which face in a particular direction

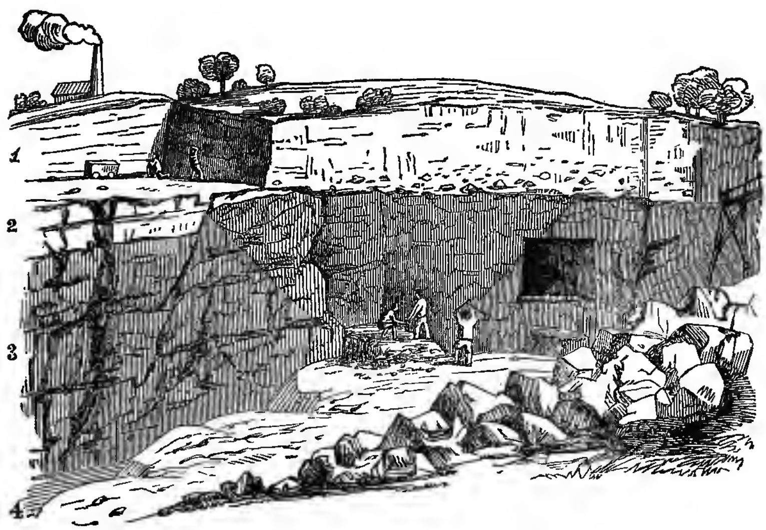
B 2

is well worthy of attention in the study of these obscure phenomena.* In other cases fragments either of the rocky sides of the fissure, or of a pre-existing vein, have been cemented together by the carbonate as a paste, and hence it ensues that whether introduced subsequently, or as in many instances simultaneously with other ores, it is very difficult to separate it from portions of galena and zinc blende in preparing it mechanically for the smelting furnace.

The hæmatite (red iron ore, sesquioxide of iron) of Whitehaven, occurs in the carboniferous limestone near the outcrop or surface edge of the slaty rocks upon which that formation rests. The greater part of the excavations from which it is extracted are subterraneous, and so extensive is often the mass of iron ore in which the workings are carried, that it is difficult in such situations to obtain a clear idea of the nature of this important deposit. But at a place called Todholes, near Cleator, an open work has for some time been in operation, which throws great light on the subject. A slight anticlinal axis has brought the iron ore to within a small distance of the surface, and the superficial covering of 15 to 20 feet in thickness, which contains very numerous angular fragments of gray limestone in its lower portion, being removed, the red iron ore is worked as a quarry. The floor of the deposit is a white and red mottled shale, almost of the nature of a fire clay, and is evidently a bed belonging to the limestone series; bore holes have been sunk in it to a depth of 30 or 40 feet without meeting with any other material. The surface of this shale is very uneven on a large scale, although the actual planes are smooth, and frequent sudden depressions or ridges throw it up or down for a few feet, disturbances which appear to be regularly followed by the superimposed hæmatite. Between the shale and the iron ore there lies, very generally, a band of conglomerate, from 3 to 8 inches thick, of small pebbles of white quartz. The mag-

* See specimens in the Museum of Practical Geology, wall case 30.

nificent bed of hæmatite which then follows, varies from 15 to upwards of 30 feet in thickness (rarely, as in Big Rigg Moor, as much as 60 feet), and is for the most part a dense mass of red ore subdivided by irregular and nearly vertical joints. Small cavities rarely occur, adjacent to which the ore assumes those botryoidal forms commonly termed "kidney ore," so well known in mineralogical cabinets, and which exhibit this mineral in a high state of purity. In such parts of the mass, rock crystals frequently occur, and calcareous spar and arragonite appear to be the substances which were last crystallised in the hollows.



Section of Hæmatite at Todholes.

1. Drift with limestone fragments.
2. Impure limestone "roof."
3. Hæmatite, 20 feet thick.
4. White "shale floor."

With a general parallelism to the floor of the deposit, two and sometimes three bands of greenish black shale, from 1 to 8 inches thick, are distinctly interstratified with the iron ore; and the presence of these partings, with the overlying roof of impure limestone which makes its appearance on the dip,

leaves on the mind almost a conviction that the hæmatite occurs as a true bed.

And yet it is difficult to remain satisfied with the view of the regular contemporaneity of the ore with the limestone strata. In other mines of the district the presence of a definite and nearly vertical boundary along one side of the workings is more nearly akin to the phenomena of a vein, and it is very possible that a systematic examination of the whole group of localities might lead to the assigning of a later date for the introduction of the iron ore into chasms and hollows which had been formed in the already consolidated beds, and thus bring the nature of the repositories of Whitehaven into coincidence with the more clearly marked ores of Ulverstone.

There seems occasionally to be a second bed, in a somewhat higher position, which rests upon a limestone floor; but hitherto so small an area has supplied the requirements of a single mine that the physical structure of the district is very imperfectly understood, both as regards the extent of these unrivalled deposits and their exact position among the members of the mountain limestone.

A shaft which has recently been sunk at High House near Cleator, through a greater depth of cover than usual, yields the following section:—

	Ft.	In.
Dark Shale - - -	156	0
Coarse Grit, called "Millstone" Grit	36	0
Shales - - - -	30	0
"Whirlstone" - - -	12	0
Shales - - - -	54	0
Red Limestone - - -	7	0
Shale - - - -	1	8
Hæmatite pierced to depth of -	32	0
	328	8

When the ore is worked as a mine, galleries are driven out from the shaft 14 or 15 feet in height, forming "rooms" with substantial pillars left between them; and after a certain area has thus been prepared, the pillars are "robbed," the roof

falls, and the surface of the land commonly gives way. The depressions which ensue and often become pools of water, with the crushing action on the neighbouring workings, render the last stages of the operation somewhat insecure, and necessitate special caution.

A small proportion only of the ores of the Whitehaven district, is smelted on the spot. The coal of the neighbouring field is ill suited for smelting purposes; and the admirable coke of the Newcastle district has to bear so expensive a carriage that but one ironwork, that of the Whitehaven Hæmatite Iron Company, has, for some time past, been in action. This establishment, situated near Cleator, is placed close upon the edge of the coal field, and possesses three blast furnaces, smelting no other ore than that of the district, which the company purchases from its neighbours. Hot blast is employed, and a certain quantity of shale has to be added to the usual materials, in order to supply in conjunction with limestone the requisites for a slag.

Iron Ore Masters of the Whitehaven District.

1. Ainsworth and Co., *Cleator.*
2. John Stirling, *Todholes.*
3. Messrs. S. and J. Lindow, *Bigrigg Moor.*
4. Anthony Hill, *Bigrigg* and *Crowgarth* mines.
5. Hesket Iron Ore Company, *Hesketpit.*
6. Richard Barker.
7. Henry Attwood and Son, *Woodend* and *Berks* mines.
8. Messrs. Tulk and Ley, *Agnes* and *Yatehouse* mines.
9. Parkside Mining Co., *Parkside* and *Goosegreen* mines.
10. S. W. Smith and Co., *High House* mine.

The quantity of hæmatite ore sent from Whitehaven by sea and by railway amounted in the year ending the 25th March 1855 to 192,312 tons, besides what was smelted in the three furnaces of the Iron Company at Cleator.

On the north side of Morecambe Bay the promontory of Low Furness, between the slate hills which rise at the back of Ulverstone and the New Red Sandstone forming the site of the venerable ruins of Furness Abbey, is composed of the

carboniferous limestone, covered up for the most part with drift or "till."* Over an area about six miles long and four broad, red hæmatite has been worked in numerous localities, and in some of them from a very early period. Neither the underground workings, however, nor the phenomena visible by daylight enable one to arrive at a very satisfactory conclusion as to the character and origin of these vast masses of rich ore.

At Stainton, south-east of Dalton, where two mines are in work, the excavations have left open a yawning chasm of 20 to 30 feet in width, ranging about North by East, with walls of gray limestone inclining slightly to the south-west. The appearances are so closely akin to those of a regular lode, that although the depth reached by the shaft is 60 yards, there seems good reason to expect the ore to continue in depth.

Less distinct are the features of the deposits in the Lindale district, and west of Dalton. Among the more remarkable for extent are the Lindale Moor mines, worked to a depth of about 70 yards, but to a width sometimes almost as great. Huge excavations are thus formed in a mass of solid ore "as large," according to the saying of the district, which recals the comfortable status of the Furness churchmen, "as a tithe barn." The result has been the collapse of the surface of the ground into a deep gully for a quarter of a mile in length. The direction of the fissure is north-west and south-east, and it was asserted by the manager that he had found slaty rock to form the northern wall, limestone the southern. It is remarkable that in this and several of the neighbouring veins, a portion only of the ore, and generally adjacent to one wall, is of the compact character exported for smelting purposes, and thence termed "blast ore." A great part is often filled with "raddle," a light and less coherent aggregate of ex-

* For a sketch of the geology of this district, see a paper by Mr. Binney, in the 8th volume of the Manchester Literary and Philosophical Society's Memoirs, 1848.

tremely delicate filmy scales of micaceous iron, soiling the finger on the slightest touch, and sometimes enclosing small portions of the more compact kind; it is sold as "puddling ore," for the purpose of forming the bottom of puddling furnaces, at a higher price than the "blast ore."

Close upon the boundary of the Silurian rocks (the Coniston or Furness grits of Sedgwick), at Whinfield Farm, are the mines of Carr Kettle and Gillbrow, in which the ore-bearing deposit takes a parallel course, at the distance of only a few yards from the former. And the circumstances both of limited length, great width, direction, and material of the deposits are similarly repeated at Whitriggs, Crossgates, and Eure Pits.

On the north of the town of Dalton, at Rickett Hills, Elliscales, and Mousell, the hæmatite has been worked in several isolated repositories, described as of a "dish shape," in which the excavation has been stopped on all sides by limestone; several of these, whose boundaries have been ascertained, run from 50 to 60 yards in width, and 15 to 20 yards deep, having no cover over them but the "diluvium," or drift. At Mousell some open works now in activity present a mass of the soft ore above described, varied occasionally by harder portions which often have a fragmentary appearance, and more rarely by interspersed patches of a white slightly coherent sandstone. No regularity of arrangement is observable, no resemblance to the character of a lode, except in an occasional piece of limestone wall, which suggests as much the idea of the side of a channel eroded by water as of a vein fissure. Numerous smooth faces or heads, exhibiting the striæ which are generally ascribed to attrition, intersect the mass of iron ore near its boundary, proving the fact of disturbances or settlements after its first consolidation.

Between Dalton and the western coast, another very remarkable tract of ore is worked at the Park and the Roanhead mines. Limestone surrounds its irregular margin, but rather

in the form of two slightly connected basins than of a vein. The hæmatite is often of an extremely fine and crystalline character, the fibres of its spheroidal mammellated aggregates being sometimes more than 6 inches in length.*

What with the richness of the ore and its extent, this place has few rivals in the world; you may proceed 4 or 500 feet in either direction in one solid mass of this valuable substance, and nothing has yet been seen of the bottom of it.

The natural cover of the deposit is a loose sea-sand overlaid by some yards of till or thick clay; and the incautious entrance into old workings, or a sudden fall of roof, have several times liberated the quicksand saturated with water, and produced ruinous results. A sudden incursion of this kind, the day before I visited Roanhead in January, 1856, may be cited as an example of the accidents to which these mines are subject. The blow of a pick into some old workings had formed a small opening, which, whilst the men in headlong flight barely escaped to the shaft, burst forth in a huge torrent of sand and water, choking in a very few minutes the galleries of the mine, breaking the pumping machinery and precluding access to all the lower workings. During the night the surface of the ground cracked and rent in various directions, the roadway and part of an adjoining field sunk in, and the crush having then abutted on solid material, it became possible with safety to commence to repair the disaster.

In the ordinary process each stage of the working is 9 feet high, and one horizon is entirely cleared out before the next beneath it is commenced; the roof is meanwhile partially supported by strong timber framing, so that when several such stages have been exhausted, the place of the ore is occupied by a certain quantity of refuse and by a collapsing forest of Baltic pine. No precautions can long save a shaft, except of the smallest dimensions, placed in such a subsiding mass. An attempt was made at Stainton, not long

* See specimens from Roanhead in Museum of Practical Geology, wall case 48.

since, to work by means of a shaft 24 feet long by 12 feet broad, in opposition to the experience of the miner; it soon began to yield, various devices were employed to keep the closing walls apart, but in vain; the whole fabric went down together, and has left scarcely a wreck behind.

It is but a few weeks since a "run" of this kind took place at Cleator, and an unfortunate man was overwhelmed by the falling ground. In vain the miners laboured, for days together, with the gallantry they always display in endeavouring to rescue even the mutilated body of a comrade, in vain the managers aided with all their means, the crush only became more hopeless. The attempt had to be abandoned, and the burial service was read at the surface over the spot where the poor fellow lies buried far beneath.

The shafts of the district, whether thus placed, or more securely at some distance from the ore, are much better fitted with apparatus for raising the mineral than in most of our metalliferous mines; steam engines, and in many instances the "water balance" are adapted to this purpose, and the waggons are drawn in cages running against slides. It would be impossible, without devoting much time to the subject, to speak critically of the other arrangements for the practical underground operations.

Very large quantities of the Ulverstone ore are shipped for the supply of Staffordshire, South Wales, and other districts; considering its quality, it brings but a low price, viz., from 11*s*. 6*d*. to 13*s*. 6*d*. per ton.

The usual rate of royalty paid to the "lords" is 1*s*. 3*d*. per ton of 21 cwts. And when we compare this with the very low dues, often only a third of that amount, taken by the lords of the newly discovered Cleveland and Northampton ores, it would appear that, accidentally, a check is given to the production of a good ore, a premium is placed upon the extraction of inferior ores, and—if with due diffidence it may be said—upon the consequent deterioration of iron.

The effect is moreover heightened by the high rates charged by the new railway for the conveyance of the ores over very short distances; although in this respect Ulverstone has taken precedence of the Cleator district, from which the ore is still conveyed by carts along the ordinary roads.

A small amount of the Ulverstone hæmatite is still smelted with charcoal at the furnaces of Newland, Backbarrow, and Duddon, one of which only is in blast at a time: and this forms the only relic left in England of the old mode of production, so completely has the introduction of coal swamped the use of vegetable fuel.

The following are the workers of mines in the Furness district:—

Harrison, Ainslie, and Co., *Lindale Moor, Whitriggs, Gilbrow.*
Schneider, Hannay, and Co., *Park, Mousell, Whitriggs, Old Hills, Newton.*
C. S. Kennedy, *Roanhead.*
Rawlinson, Jos., *Crossgates, Carr Kettle, Rickethills.*
H. Kennedy and Co. or Ulverstone Mining Co., *Lindale Cote, Eure Pits.*
Brogden and Co., *Stainton, Adgarley, Bolton Heads.*
Fell, Messrs., *Stainton.*
Ashburner, Geo., *Elliscales.*

The total quantity of hæmatite exported from the Ulverstone district amounted in 1854 to no less than 354,685 tons, making with the amount raised near Whitehaven, and that used in the neighbourhood, a grand total of 579,924 tons as the year's production of these two important sources of our richest iron ores.*

In other parts of the northern counties, hæmatite occurs in less important deposits, especially in certain veins in Derbyshire, but since their produce is not included in the present series of analyses, we may omit their detailed description.

* These details are extracted from the statistics of iron and coal compiled by Mr. R. Hunt, F.R.S., and published in the Memoirs of the Geological Survey. Longmans, 1855.

Ironstones of the Coal Measures.

The ores which are interstratified with the other rock layers in all the coal fields of Britain are, to the uninstructed visitor, among the least attractive specimens of the mineral kingdom. Gray, brownish, or black lumps and nodules, they present none of the symmetry of crystallization, no transparency or brightness of colour, to invest them with external interest. But it is mainly to these commonplace-looking ironstones, to their good qualities, and to the fortunate manner in which they occur associated with the beds of fossil fuel, that the manufacture of iron owes the gigantic strides which it has made within the last half century, and to which Great Britain must ascribe her remarkable pre-eminence in this amazingly important branch of industry.

Although the clay ironstone (argillaceous carbonate of iron: *Sphärosiderit* of the Germans) occurs more or less in all our coal-bearing regions, it is developed in certain among them in too small a quantity to render it capable of profitable extraction. In some of them it is the only ore which is employed for smelting, whilst in others it is used in conjunction with richer ores conveyed from a distance, and in some few instances forms so small a proportion of the total material which is treated as to hold but a low rank in importance.

Of the northern districts included in the present paper, Northumberland and Durham fall within the latter category. On the western or outcrop side of that coal field, the numerous furnaces of Consett, Tow Law, and others, were erected in localities where a certain supply of the clay ironstone was obtainable from the lower portion of the measures, principally beneath the beds of coal which are worked for export, and above the millstone grit. The courses of "stone" occur in close proximity to those coal seams which within the last few years have risen into great importance from their excellent coking properties, but their development

is so partial that although when near the outcrop, at the Consett Works, west of Gateshead, they formed at first a chief part of the raw material required, their extraction has now ceased, and at the distance of a few miles, around the Marley Hill and Pontop Collieries they are said almost entirely to have thinned out. At Tow Law, which is placed farther south, in a similar position as regards the outcrop, these ironstones are still raised. The lowest important seam of coal in the series is here worked for the furnaces, varying from four to six feet in thickness (where it is not split or subdivided), and called the Beaumont, *alias* the Harvey Seam.

This region of the best coking coal, which extends from Wylam in the northern to St. Helen's Auckland in the south-western part of the field, has been within the last six years brought into an interesting relation with the north of Yorkshire. Its indigenous iron ore was so insufficient in quantity that ruin seemed to impend over some of the large works established there; but the spreading of the great railway net, and the almost contemporaneous discovery of the ores of the Lias in Cleveland totally changed the scene. No longer need the workers of the coal measures to repine over the paucity of their nodules; the admirable coke which they produce is exported to manufacture iron at Middlesbro' in Yorkshire, and the returning trains carry back large quantities of that ore which is obtained so cheaply as to bear the expense of transit without difficulty.

In the Lancashire coal field argillaceous ironstones occur in several parts of the coal measures, but not in such abundance as to have led to their extraction for smelting purposes.

Yorkshire.

The coal field of Yorkshire may be considered, especially in respect to its iron manufacture, as admitting of division into two parts, the northern or district of Bradford, and the southern which ranges from Leeds by Barnsley to Sheffield and Rotherham.

Bradford District.—In the former portion the lower part of the strata is developed to a degree of importance not seen in the south, by the occurrence of the beds of coal and ironstone which have given rise to the establishments of Low Moor, Bierley, and Bowling, celebrated for the production of the best irons made in Britain, and to that of Farnley, which is following in the same steps. The castings from these works are largely employed for special purposes where strength and tenacity are required, as for mortars and sea-service guns; their wrought iron, the quality of which is attested by its bringing nearly twice the price of ordinary English iron, has the peculiarity of a granular structure, with a uniform, small, and brilliant grain which closely resembles the character of the Swedish bars.

It is an important fact that coal-measure ironstones are alone employed in this district, and principally from two ranges of strata called the *White Bed Mine* and the *Black Bed Mine* respectively; a third, the *Brown Rake*, was also formerly worked. Neither their quality nor their abundance have much contributed to the celebrity of the North Yorkshire iron, as the result of analysis and comparison with other coal fields will show. The superiority appears to proceed from the care and attention bestowed upon the various processes, and from the admirable character of the seam of coal, termed the "better bed," which lies beneath the ironstone, and attains a thickness of only 1 foot 8 inches to 2 feet; it differs, however, from ordinary seams in its remarkable freedom from iron pyrites and other impurities, and is exclusively used for smelting, refining, and puddling. You may pass through the thick smoke of the coking heaps or ovens without the least inconvenience from the sulphurous gases, which in the coking of most coals are so freely liberated.

An average section of the measures is as follows, the numbers prefixed relating to the series collected by Mr. S. H. Blackwell, and enumerated in the Catalogue of the Exhibition of 1851:

	Cat. 1851.
White bed Ironstone, Bierley. Analysis No. 7.	300 Top flats. 301 Low flats. 302 White balls. 303 Middle balls. 304 Low measure.
Black bed Ironstone, Lowmoor, in 18 beds. Analysis No. 8.	305 Top balls. 306 Flat stone. 307 Middle balls. 308 Rough measure. 309 Low measure. 310 Basset stone.

	Ft.	In.		Ft.	In.
Royds or Black bed COAL - - - -	1	4	to	2	3
Various measures - - - - - ; Roof of coal, black shale with numerous fish remains, and small white nodules of ironstone - -				120	0
"Better bed" COAL - - - - - - -	1	4	to	2	0
"Floor" of indurated clay with small scales of white mica - - - - - - -					
Various measures - - - - - - -				150	0
Flagstone, exported for London pavement, &c. - -					

These ironstones, as usual with their class, are exposed for many months to the weathering action of the atmosphere, in order to free them from the adhering shale; they are then calcined previously to smelting, and unusual care is taken to pick out every kind of refuse or impurity.

The higher band, the *white bed,* is characterized by the pale drab colour which pervades most of its courses, although enclosed in a darker shale or bind. The *black bed* is of the blackish gray tint more usual with clay ironstones, and occurs in detached nodules of various sizes, but, taken as a whole, smaller than those commonly worked in the coal fields.

The extension of these rows of nodules and their accompanying coal seams over other portions of Yorkshire is a question of much interest, when we know how persistent some similar beds are over very large areas. But the quality of coal in the same seam will often vary within a small distance; and ironstones, either by running smaller, or by their courses being separated by a thicker band of shale,

may become unworkable; several trials already made in search of the Lowmoor series have proved this deterioration, and although it may be predicated that the same strata may be followed up on the dip, far beyond where they are at present known, it is by no means certain that they would retain the qualities which have given them celebrity.

Southern Yorkshire.—The ironworks of this district are situate between the North Midland Railway and the line of high ground which, abounding in gritstones and flags, marks the outcrop of the lower portion of the coal measures. A beautiful district by nature, the West Riding of Yorkshire has not yet been despoiled of all its picturesque character, and specially in the iron-bearing part are the hills well clothed with wood, the valleys deeply cut and adorned by rapid streams. From the banks of the river Dun which flows past Sheffield, rise in bold masses the Wharncliffe rocks, which may be followed along the outcrop in a north and south direction, dipping with the rest of the measures towards the east, and forming the base of that portion of them which yields the ironstones and coals of the tract under consideration.

From Park Gate, near Rotherham, over Lord Fitzwilliam's fine property of Wentworth, to Tankersley, and on to the west of Barnsley, may be traced in succession many of the more important bassets of ironstone, the value of which, added to a particular method of working, has imparted a strange aspect to the surface, which is reflected in the well-executed shading of the Ordnance map.

Wherever the courses of ironstone nodules come up to within a short distance of the surface they are vigorously attacked by the small shafts termed *bell pits*, disposed in great numbers along the line of strike, at a distance of a few feet only each from the other, and arranged like the vines of Virgil,—

"All in regular order, with intervals each like the other;
"Not for the empty mind to approve the symmetrical aspect,
"But that to all alike the earth may distribute her treasures." *

The result of the *belling*, and the open work which not uncommonly accompanies it, is to leave long lines of irregular holes and pits, often so considerable as to unfit the land for agriculture, and to induce the planting of belts of trees. The ironstone *bind* or shale appears not to be prejudicial to their growth, and the strips of plantation thus offer to the eye, even from a distance, a clue to the arrangement of the strata beneath the surface.

The beds of coal and of ironstone frequently change their appellation in passing from one part of the district to another, so that it becomes difficult to identify them in distant localities without a very accurate study. The Rev. Mr. Thorpe has published a valuable aid in this direction in his Section of the Yorkshire coal field, where he has united the result of the sinkings and borings over a very large area.

The more important of the ironstones employed in the West Riding are interstratified in about 1,000 feet thickness of measures, which intervene between two well-marked beds of coal, the *Barnsley thick* coal and the *Silkstone*, and are known as the *Swallowwood*, the *Lidgate*, *Tankersley*, *Thorncliffe Black Mine*, *Thorncliffe White Mine*, and *Clay Wood Mine*.

An average section in the Wentworth district of the ironstone-bearing part of the coal measures, is as follows :—

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* "Omnia sint paribus numeris dimensa viarum,
"Non animum modo uti paseat prospectus inanem,
"Sed quia non aliter vires dabit omnibus æquas
"Terra."

VIRGIL, *Georgics*, lib. ii.

	Ft.	In.		Ft.	In.
COAL, Low Wood, Hobbimer, Elsecar or Barnsley -	6	0	to	9	6
Various measures, with several small coal seams -				180	0
Swallow Wood Mine, Milton. { 311 Flats. 312 Balls. 313 Bottom measure.					
COAL, Swallow Wood, or Strafford Main - -	3	4	to	6	0
Measures - - - - - - -				130	0
Lidgate Mine { 314 Flats. 315 Balls. 316 Bottom measure.					
COAL - - - -				1	0
Measures, near Milton - - - -				30	0
COAL, Lidgate - - - - -				2	4
Measures - - -				120	0
COAL, Tankersley thin - - - -				1	10
Tankersley Mine, or *Joan.* { 317 Top measure. 318 Middles. 319 Bottom measure. } 12 to 15 in. ironstone.				6	0
Measures - - - - - - -				66	0
COAL, Heward or Top Flockton - - -	2	0	to	4	0
Measures very variable in thickness - - -				140	0
COAL, Fenton's thin (good smithy coal) - -				2	0
Thorncliffe or *Old Black Mine,* Parkgate. } 320 Balls. 321 Holing measure. { 11 in. of ironstone.				4	0
Branch COAL - - - - - - -				1	6
Measures - - - - - - -				75	0
COAL, Parkgate, Thorncliffe thick, or Manor - -	4	10	to	7	10
Thorncliffe White Mine, or *Cowley Lane ironstone.* } 322 Flats. 323 Balls. 324 Holing measure.					
Measures - - - - - - - -				72	0
COAL, Thorncliffe thin, or Furnace - - -	2	6	to	3	0
Measures, including three thin seams of COAL from $6\frac{1}{2}$ to 18 inches each - - - - - -				140	0
Clay Wood or, *Black Mine,* Parkgate. { 324 Balls. 325 Brown George. 326 Whetstone. }				0	$5\frac{1}{2}$
Shale measures - - - - - -				36	0
COAL, Silkstone, Bromley, Sheffield, or Black Shale -				4	0

Of the ironstones which have been selected for analysis No. 9. (or 320, 321, in the Illustrated Catalogue) is the *Thorncliffe* or *Old Black Mine,* of which about 1,500 tons are yielded by one acre. Some of the larger nodules often exhibit cracks formed by contraction which have been filled

up with brown spar, the carbonate of lime, magnesia, and iron.

No. 10. (Illustrated Catalogue 322, 323*a*, 324*b*,) the *White Mine* of Parkgate, which yields about the same quantity, was formerly worked on a large scale by the Messrs. Walker, at the Holmes, and is still used by Messrs. Newton, Chambers, and Co., at Thorncliffe.

No. 11. (Illustrated Catalogue 324, 325, 326), the *Clay Wood Mine*, a brownish gray ore, produces 1,500 or 1,600 tons per acre, and, with No. 9, are the chief ironstones employed at the Thorncliffe ironworks.

The *Tankersley* or "Musselband" ironstone yields on the average about 2,000 tons to the acre, although as much as 3,400 tons has been exceptionally produced. It is so called from the great number of fossil shells (*Unio*) which characterize it, and it is probable that in a supplement the analysis of this ore also will be given.

Derbyshire.

The coalfield of Derbyshire being the extension southward of that of Yorkshire, it is easy to trace many of the same seams continuously over a very large area; and a reference to the maps prepared by the Geological Survey will most distinctly prove this point, by exhibiting, unbroken from the valley of the Don to the southern extremity of the coal district, the outcrop of the two principal beds above alluded to. They change their names in different parts of the county, but are best known under the appellations of the *Top Hard* and *Black Shale* or *Clod coal* respectively; and between these two, as in Yorkshire, all the more important measures of ironstone are situate.

The beds of ironstone are somewhat more capricious than those of coal; a few of them maintain a valuable character throughout the length of the county, but many of the rows of nodules, or so-called *Rakes*, which are largely worked in certain districts, are found to thin out or deteriorate within a comparatively short distance. Thus, a series of strata far

below the above-mentioned "Black Shale" coal, although hitherto considered of no account in the greater part of the county, are sufficiently improved at the southern end of the coal area as to have given rise to very important workings near Stanton-le-Dale.

The following general section of the portion of the Derbyshire coal measures in which most of the ironstones occur, includes the beds or seams worked at all the important localities:—

			Ft.	In.
Yard COAL			3	6
Measures, various			90	0
	Measure and Balls rake (Staveley)	327–34.		
Measures, apparently thickening southwards			75	0
COAL, Main or Top Hard (Staveley, Swanwick, &c.)			6	0
Measures			84	0
COAL, Dunsill, or Oldgreaves			4	0
Measures			100	0
COAL, Waterloo			4	0
Measures			20	0
COAL, Cannel			1	4
Measures			27	0
COAL, Tunnel			1	5
	Buff, or Cement rake, Alfreton.	341 Top measure. 342 Balls. 343 Bottom measure.	9	0
	Pinder Park rake, Staveley.	338 Red measure. 339 Balls. 340 Cockle.	6	1
	Brown rake, Butterley. 2,500 tons per acre.	344 Balls. 345 Top measure. 346 Bottom measure.	4	6
Measures			29	6
	Black rake, Butterley. 5 courses, 2,000 tons per acre.	347 Top measure. 348 Bottom measure.	4	6
Bind			1	4
COAL, Ell, Chavery or Allwoods			3	0
Measures			39	0
COAL, Main Soft, or Handley Wood			5	0
Measures, with	*Poor rake,* Alfreton; *Blue rake,* Butterley	349 *a* and *b*.; 350.	87	0
COAL, Lower or Deep Hard			5	0
Measures			69	0
COAL, Piper, or Three bedded			2	3
Measures, with	*Spring* or *Ridding's rake,* Alfreton, 341. *Old Man's rake,* Butterley, *and Whetstone rake,* Butterley.		96	0

		Ft.	In.
Dog-tooth rake, Staveley. 2,000 tons per acre.	352 White measure. 353 Sugar-plum measure 354 Marble measure. 355 Balls. 356 Snail-horn.	8	4
Called *Wallis's rake* at Butterley.			
COAL, Dog-tooth, near Chesterfield		3	0
Measures, with *Brown measure,* Clay Cross, 357 (2 ft. 10 in.)		39	0
COAL, Furnace or Tupton		4	6
Measures		15	0
Three-quarter Balls. 5 courses, at Clay Cross.	360	10	8
COAL, Three-quarter or Lees		2	0
About the same place, *Nodule rake,* Morley Park, 1,600 tons per acre.	358 Cinder measure. 359 Balls.		
South of Clay Cross this is called *Dog-tooth rake.*			
Measures		27	0
Black Shale rake, 4 to 7,000 tons per acre. Near Chesterfield divided into top and bottom measure by 12 ft. of bind.	361 Whetstone. 362 Chitter. 363 Cheeses. 363*a* Bear. 364 Top blues. 365 Lower blues. 366*a* Old man. 366*b* Old woman.	16	0
	367 Smooth chitter. 368 White balls. 369 Flampard. 370 Red measure 371*a* Dun. 371*b* Beams. 372 Roof measure. 373 Bottom balls.	21	0
Striped rake, Kirk Hallam, 2,500 tons per acre.	374-5, 6.		
Shale, &c.		3	6
COAL, Yard or Roof		2	8
Shale and thin coals, averaging		10	0
COAL, Black Shale or Clod (Sheffield seam)		5	0
Measures		37	0
Green Close rake, Morley Park.	377 Balls and bottom measure.		
COAL, and "Bat" or Black Shale		5	0
Hollyclose rake, Morley Park.	378.		
Measures with *Black or Ketlands rake,* Morley Park, 3,000 tons per acre.	379-84	216	0

		Ft.	In.
Baconflitch rake, Alfreton.	385 *a* & *b*.		
Yew-tree rake, Morley Park.	386.		
COAL		1	6
Measures		66	0
COAL, Kilburne, Buckland-hollow, or Honeycroft		5	0
Clunch		3	0
Honeycroft rake, Stanton. 6,000 tons per acre.	387 Chitters. 388 Tufty balls. 389 Barren beet. 390 Grindstone measure. 391 Grinder's wife. 392 Big balls. 393 Bottom flats. 394 Brick measure.	45	0
Measures, without "rock" or sandstone		252	0
Civilly rake, Stanton. 4,000 tons per acre.	395 Ratchell measure. 396 Chance balls. 397 Bottom measure. 398 Chitters. 399 Coal measure.	60	0
COAL, Furnace		2	3
Dale Moor rake, 3,000 tons per acre.	400 Clunch balls. 401 Roof measure balls. 402 Roof measure. 403 Over bottom. 404 Bottom balls.	21	0
Measures		96	0
COAL, Bottom, resting almost immediately upon the coarse grits, commonly called Millstone grit		2	0

Among the beds thus enumerated, those which lie above the Top Hard coal have not been very generally worked, and are thus difficult to identify in isolated localities. This applies especially to the measures called the *Brierly Bank rake, Inkersal,* and *Measure and Balls rake* of the northern part of the field, and the numerous bands of ironstone detailed in the carefully executed sections of the Butterley Company in the southern portion of the district.

The total thickness of coal measures in the above section is 1,600 feet; and to this may be added about 400 feet for the ground, containing also several seams of ironstone and coal, which caps towards the east the more important portion which we have detailed. A few comments on some of the beds are appended, taking them in the descending order of the section.

Below the Tunnel coal, and about 50 feet above the well-marked and continuous seam called the Main Soft coal

(largely worked at Shipley, Babbington, &c.), occur some of the more productive measures, the *Pinder Park* of Staveley, and the *Ruff* or *Cement rake* and *Brown rake* of Alfreton and Butterley.

The *Dog-tooth rake* (Chesterfield) is one of the most important in the field, and remarkable from the fact of one or more of its beds being almost entirely made up of fossilized bivalve shells, the *Unio* of many authors, more recently termed *Cardinia* and now *Anthracosia.*

A section of the beds accompanying it at Unston, near Dronfield, was well exposed in the *bell pits* by which it was worked, and in adjacent pits.

GRAY SHALES WITH IRONSTONE.

	Ft.	In.
Dog-tooth measure	24	0
Bearstone, or band of cone-in-cone structure	0	9
Shales	9	0
Bluish bind with two courses of ironstone	4	0
COAL	1	2
Hard floor, with Stigmariæ abundant, very similar to "Gannister"	1	0
Fire-clay	4	0
COAL	1	9

The fossil shell which occurs so abundantly in this ore as greatly to affect its chemical composition is in many districts preserved with the utmost sharpness, and is referred by Mr. Salter to the species *Anthracosia agrestis* (Brown), *acuta* (Sow.), and appears to be identical with that from the Blue vein, Ebbw Vale, South Wales. It will be seen from the Analyses XVI. and XVII. that a great difference exists in the composition of different bands of this "measure;" and that in Nos. 354 and 356, the first of which is a perfect mash of shells converted into crystalline carbonate of lime, the per-centage of phosphoric acid, of organic matter, and of lime is greater, whilst that of iron is considerably less.

This shell, *Unio* or *Anthracosia*, probably of several species, is found more or less abundantly in all the ironstone beds, from the top of our section down to the Black Shale rake. In the lower measures it is much more scarce, or is even altogether wanting, although in some of the very

lowest it again appears more numerously. The *Anthracosia bipennis*, which occurs in No. 330, the Measure and Balls rake, is found also in the Low Moor ironstone, and at Mold in Flintshire. We cannot but marvel at the wondrously prolific condition of the water in which these creatures lived, evinced as it is by banks of innumerable shells, piled upon one another, often to several inches in depth, and extending over many miles in area.

On the prolongation of these beds to the southward much confusion arises in consequence of the same name being given by the miners to any ironstone of similar structure; and thus the measure situated at the same distance above the Furnace coal at Codnor Park, Butterley, as the Dog-tooth at Chesterfield, and very full of the same bivalve shells, is termed *Wallis's rake*, and is separated by only a few feet of bind from a measure above it called the *Whetstone rake*. Wallis's rake appeared to be a great favourite with the men, being eulogised as the best ironstone in England, and asserted to contain an impossible proportion of iron.

Below the Furnace coal, the *Three-quarter balls* form a very productive working at Clay Cross. Several of these lower ironstones contain besides bivalve shells the remains of calamites and other coal plants, very commonly forming the surface of the nodule, and completely changed into ironstone. It is probably the same measure which, occurring south of Clay Cross, and especially at Butterley, about 10 feet below the Furnace coal, is called the *Nodule rake*, though by some it is termed the *Dog-tooth*. In both are numerously found small tubular hollows left by the rootlets of Stigmaria, and not unfrequently filled with zinc-blende.

The most remarkable of all the ironstones of the district is the so-called *Black Shale rake*, or *Striped rake* of the south, which occurs at a varying distance above the Black Shale or Clod coal. Its fullest development is met with between Dronfield on the north and Butterley on the south, and nowhere is it so well seen as at Hady, near Chesterfield, where it has long been actively worked for the Staveley iron

furnaces. At this place it consists of two banks of gray shale, of 15 and 21 feet thick respectively, loaded with numerous rows of nodules, and having between the two 12 feet of unproductive shale. Each separate measure is well known to the workmen by distinctive character and by name; and as the Black Shale ironstone is not less interesting to the miner than as an unique specimen of this kind of accumulation to the geologist, a detailed section of it is here attached.

	Ft.	In.
Whetstone, lean or poor measure, not got - - -	0	1
Shale - - - - -	1	6
Single balls, do. - - - -	0	0½
Shale - - - - - -	1	6
Double chitter, do. brown rough nodules - -	0	2
Shale - - - - -	3	0
Cheeses, good measure - - - -	0	1½
Shale - - - -	2	0
Bearstone, capped with cone-in-cone, lean, rough texture -	0	1
Shale - - - - -	2	3
Blues, upper, good and rich, flat nodules -	0	1
Shale - - - - -	1	3
Blues, lower, do. do. - - - -	0	1½
Shale - - - -	2	0
Old man, good; nodules often thick, average -	0	2
Shale - - - -	1	6
Old woman, or *sheeting*, good; flat nodular	0	1
Total of top measure - -	15	11½
Intermediate Bind, with an irregular bed of ironstone, 18 ins. from bottom -	12	0
Smooth chitter, a lean measure, brown and rough	0	2½
Shale - - -	3	6
Flampard, a very rough, granular-structured stone; lean -	0	3
Shale -	2	0
Red measure, good; cleavage planes, with white coating	0	1½
Shale - - -	3	0
Chance measure, lean - - - -	0	0½
Shale - -	1	6
Dun lining, do., black, with small crystals of pyrites -	0	1
Shale - - - - - -	1	0
Dun measure, good; thick black nodules - -	0	2
Shale - - -	2	0
Over lumps, good; cracks coated with white powder	0	1
Shale - - - - -	1	0

	Ft.	In.
Nether lumps, good; cracks coated with white powder	0	1
Shale	1	6
Overbottoms, do.	0	1½
Shale	1	6
Roof measure, do. rough and black	0	1½
Shale	1	6
Bottom measure, do.	0	1
Shale	1	6
COAL smut, 2 ft. 3 in. above the roof COAL.		
Total of lower measure	21	½

Among the above, the "Cheeses" are remarkable for the symmetrical cracks caused by contraction in the interior. These are mostly filled with a carbonate of lime containing some iron and magnesia, and, where an open space has been left, crystals of zinc-blende are also present.

The "Old man" and "Old woman," gray stones of very compact texture, and with a fracture tending to conchoidal, exhibit numerous cracks of the same description, which, besides a similar mixed carbonate, present abundant crystals of zinc-blende, and isolated crystals of galena (sulphide of lead) in well-defined crystals combining the faces of the cube and octahedron. Copper pyrites and iron pyrites also occur occasionally in the same manner, sometimes even in the partial hollows left around the cast of a fossil shell; and it need scarcely be pointed out what an important bearing on the formation of mineral veins is afforded by the presence, under such circumstances, of the metallic sulphides. It is, moreover, remarkable that they occur more abundantly in the vicinity of the small faults which traverse the measures and which would appear to have been the channels for the passage of waters holding these substances in solution.

The working of this ironstone, when it gets beyond the reach of open work or bell pits, is conducted on a peculiar plan. A number of shafts are sunk at small distances asunder, commanded by one steam-engine, which, by means of a large horizontal drum and chains, may be made to wind the material from above twenty shafts at once. Along the sides of the levels of communication, which are driven in the

lower measures, stalls or "holes" are opened, at the most about seven yards by nine in area, with but a few feet of wall between them. The lower ironstones are first extracted, and the waste shale or bind, being thrown under foot, suffices so to raise the floor that the men are kept continually near the roof of the upward advancing excavation; and, if the ground be strong enough, one stall may be "holed" into the other. Upon this system the upper range of measures is first extracted; and, when the ground has sufficiently settled, the lower range is commenced upon.

As regards the ironstones in the next 300 feet below the Black Shale, they are not worked over a very large area, being almost confined to the district of Alfreton and Morley Park. Those from the latter locality are mostly of a pale drab colour.

Below the excellent seam of coal called the Kilburn, occurs a band of ironstone, the Honeycroft, which runs continuously from Buckland Hollow, near the Ambergate Station, to Stanton, where it is very productive. No. 388, the "tufty balls," contains fossil shells and remains of fish, with calc-spar and zinc-blende lining the cavities. 388 and 390 have a much rougher texture than the rest.

In the *Civilly rake*, which occurs above the Furnace coal, Stanton, 395, the "Ratchell measure" is a rough textured stone, containing minute scales of mica. 396, the "chance balls," exhibit cracks lined with crystalline barytes of white and pinkish hue.

The upper measures of the *Dale Moor rake*, the lowest known in the Derbyshire coal-field, Nos. 400, 401, light drab stones in colour, are remarkable, especially the upper one, for the number of remains of plants, particularly of rootlets of *Stigmaria*, which they enclose. 402–3, 4, are black, rough-textured, large nodules; and No. 404, the "bottom balls," is especially remarkable for the discovery of a great number of well preserved entire fishes, generally from four to seven inches in length. They belong to the genera *Palæoniscus* and *Platysomus*, and it would appear

that the workings at Stanton had at one time reached a shoal of them, so numerous were they in one comparatively limited spot.

From the fact that the beds so close above these fish nodules exhibit abundant remains of plants, it would appear highly probable that the fishes were left in a shallow pool at low water, or were by some similar means cut off from escape seaward, and having thus soon perished were covered up and entombed in the irony mud which was brought down by fresh water, and which, whilst yet soft, aggregated around their bodies into lenticular nodules.

The great number of courses in these lower ironstone measures, coupled with the considerable thickness of the shales in which they occur, rendered it advisable to work them by opencast on a very large scale. The workings, which have supplied for several years the Stanton furnaces, were opened at a short distance to the south of that establishment, and were continued downwards in the very moderate dip of the strata, till the face of the quarry, becoming 40 or 50 feet in height, was hazardous to the men employed upon it. The ore was drawn up an incline by a stationary engine, and the bind or shale thrown back to fill up the vast cavity.

Ironstone of the Lias.

Not more than eight years have elapsed since attention was accidentally directed to loose masses of a ferruginous substance which were strewn over the beach on the north-eastern coast of Yorkshire; and experiments made at the furnaces of Messrs. Bolckow and Vaughan, near Bishop Auckland, proved it to be worth smelting as an ore of iron. Yet some little time elapsed before it was observed that these loose blocks had fallen from the higher ground, in which a massive bed of the same material might be traced by its outcrop for miles and miles along the escarpments of the Cleveland Hills.

On the coast line, and again at a small elevation above the flat land which extends from Redcar to Middlesboro' on Tees, there crops out to the surface a solid stratum

of no less than 15 feet thick of an ironstone which, although said to contain on an average about 30 per cent. of iron, presents such an appearance as readily to account for its value being so long overlooked. Situate about the middle of the lias formation, in a position corresponding to the "marl-stone," it would easily pass muster for an ordinary sandstone with only its external surfaces more or less rusted by the peroxidation of iron. It is, in fact, a sometimes massive, at others interlaminated with shaley bands, deposit of a greenish or gray colour, divided by a system of nearly vertical joints, having a structure generally oolitic, and in the spherules of which Mr. Bowerbank recognizes, under the microscope, concentric coatings. It contains numerous well-known fossils of the marlstone, especially *Belemnites* and *Pecten æquivalvis*, many of which are in a very fine state of preservation.

This remarkable seam extends over a region of some hundreds of square miles, although with a gradually diminishing thickness as it is traced southward to Gainsborough and then to Thirsk, where it appears to thin out. It is capped by sandy shales containing scattered nodules of ironstone, and ultimately, above the *Marlstone series* to which it belongs, by the upper lias shale, so well known along the Whitby coast for its fossils, jet, and the application of some of the beds to the manufacture of alum.

The upper lias shale, although 200 feet thick on the coast, is much less towards its western limit; and thus in the Thirsk district the marlstone is succeeded, within a very small distance, by the lower oolite series, which there acquires practical importance from containing several bands of workable ironstone.

The great lias bed is nowhere better developed than at Eston, near Middlesboro', where, as well as for some miles to the southward, it is now actively worked. Self-acting inclined planes have been carried up the lower slope of the hill and lead into the workings, which are conducted in a series of chambers and massive pillars, generally to the full height of the seam.

Had the landowners and their iron-making lessees been gifted by the Muses (too often scared away on the unfolding of the ledger) with a sense of the picturesque, some of these rubbish-strewn hill-sides of Yorkshire would have rivalled the chambered precipices of Egypt or Arabia Petræa. A great change in the appearance of the district has been brought about, but at present the alteration is not for the better. A very numerous population has been hastily accumulated around the base of the hills, and from the very mode of its being brought together, will require great efforts on the part of the managers and owners of works to mould it into a state of order and moral well-being.

Although of so few years standing, these iron mines now supply the ore to above sixty blast-furnaces; and thirty furnaces, besides establishments for the manufacture of wrought iron, have sprung up, in despite of the distance from coal, in and about Middlesbro'.* It may hence be estimated, that from this new source upwards of a million of tons of ironstone are annually extracted.

Analyses of Iron Ores.

Description of the various Processes employed, and Experiments in proof of their Accuracy.

(By A. Dick.)

Three principal Methods of analysis were employed, which, in the subsequent descriptions, will be denoted as Method No. I., Method No. II., or Method No. III., according as one or other was employed in the particular analysis. Any special modification will be mentioned in the account of the analysis in which it was employed.

Details of Method No. I.—1. A portion weighed from the stoppered bottle containing the fine powder was digested in strong hydrochloric acid till no further action seemed to take place, and was boiled for about 15 minutes before dilution and filtration. The undissolved portion was thoroughly washed with hot distilled water, dried, ignited, and weighed, the usual precautions being taken to prevent absorption of moisture.

* It is intelligible that the discovery of neighbouring coal should be regarded as a desideratum; but it says little for the spread of sound knowledge in the district, that at the present time a trial for coal should be in operation at Redcar, where people, more sanguine than prudent, are founding their hopes on the very shales, loaded with lias fossils, which, as has been pointed out to them by a geological neighbour, distinctly warn them to desist.

2. The iron in the filtrate was peroxidized, if necessary, by nitric acid or chlorate of potash; excess of ammonia was added, and filtration conducted rapidly.

3. The lime was precipitated from the filtrate as oxalate, converted into carbonate by ignition, and either weighed as such after evaporation with carbonate of ammonia, or else moistened with sulphuric acid, and, after expulsion of the excess of acid by heat, weighed as sulphate.

4. The magnesia was precipitated by phosphate of soda and excess of ammonia. Generally about 24 hours were allowed for the separation of the precipitate; it was then collected on a filter, washed with ammonia water, dried, ignited, moistened with a few drops of nitric acid, re-ignited, and weighed. The precipitate obtained by this method generally contains some flocculent matter which was found to be phosphate of alumina; the alumina having been retained in solution by the ammonia (2).

5. The precipitate (2), consisting of all the iron, alumina, phosphoric acid, and manganese (except a trace of the last which accompanies the lime), together with small portions of silica and lime or magnesia,—the former combined apparently with alumina, the latter with a portion of the phosphoric acid,—was dissolved in hydrochloric acid, then supersaturated with caustic potash, boiled in a platinum basin, and filtered. The filtrate was acidified with hydrochloric acid, boiled, after addition of some chlorate of potash to destroy the organic matter arising from the action of the potash on the filter, nearly neutralized with ammonia, and finally rendered alkaline with carbonate of ammonia. The precipitate was ignited and weighed; the phosphoric acid contained in it was determined by the tartaric acid process (see page 49), and subtracted from the previous weight to ascertain that of the alumina. The amount of phosphoric acid so determined is never exactly the correct one, owing chiefly to its containing a little silicate of alumina. The phosphoric acid was always determined by another experiment.

6. The precipitate produced by caustic potash was dissolved in hydrochloric acid, and the iron precipitated as succinate, collected on a filter, re-dissolved and re-precipitated by ammonia, ignited, and weighed. So obtained, it is never perfectly pure, owing to its containing a little phosphoric acid, combined apparently with lime or magnesia, and silica, combined apparently with alumina; neither of these combinations being decomposed by boiling with caustic potash. It was accordingly re-dissolved in hydrochloric acid, and filtered from a portion of the silica which becomes insoluble at this stage, and which was ignited and weighed. It may be here noted, that a very small quantity of silica cannot be separated from a very large quantity of iron by the ordinary evaporation process; so that the separation of this small quantity of silica could not be effected by evaporation of the original hydrochloric acid solution. The phosphoric acid contained in the precipitate was determined by the tartaric acid process; so obtained, it generally contains a small quantity of silicate of alumina. This phosphoric acid and silica subtracted from the original weight gave what was taken as peroxide of iron; though it no doubt still contained a very small quantity of other substances.

7. The filtrate from the succinate of iron was rendered alkaline by ammonia; a few drops of bromine were added, and it was left 24 hours. The precipitate was ignited at a bright red heat and weighed as $Mn^3 O^4$.

8. The insoluble portion (1) was fused with excess of the alkaline mixture obtained by decomposing Rochelle salt by heat, and washing out the mixed carbonates. The fused mass was dissolved in dilute hydrochloric acid evaporated to dryness, the residue moistened with strong hydrochloric acid, and left 24 hours;

it was then digested with hot water, filtered, and the silica ignited and weighed. Its purity was tested by dividing it into two portions, and treating one by hydrofluoric acid, and the other by caustic potash; any impurity was separated if the amount was weighable.

9. The filtrate (8) was rendered alkaline by ammonia, and filtered. The precipitate was either ignited and weighed, the iron being afterwards separated and subtracted from the previous weight, or else it was at once dissolved in hydrochloric acid, and subjected to the potash treatment described in (5) and (6), except that, since it contained no phosphoric acid, this part of the treatment was not needed.

10. The lime and magnesia in the filtrate (9) were determined in precisely the same manner as in the hydrochloric acid solution of the ore.

11. *Alkalies and organic matter.*—It was ascertained that nearly the whole of the alkalies was contained in the residue insoluble in hydrochloric acid. A weighed portion of the ore was digested in hydrochloric acid, the insoluble residue collected on a filter, and washed. The latter was then dried, till, by a little management, it could be collected together and removed from the filter without detaching a weighable amount of the fibre of the paper. It was then exposed in a platinum vessel to the vapour of hydrofluoric acid in Brunner's apparatus till decomposed. The product was evaporated with strong hydrochloric acid, the residue moistened with dilute hydrochloric acid, and the undissolved black matter collected on a small weighed filter, dried and weighed. As it generally contained a small amount of undecomposed inorganic matter, it was ignited and the ash weighed and subtracted. The filtrate from the organic matter was added to the original hydrochloric acid solution; the mixed solution was treated by the ordinary caustic baryta process for alkalies, which were weighed as chlorides.

12. *Sulphuric acid and sulphur.*—A weighed portion of the ore was digested in hydrochloric acid, the solution filtered and the sulphuric acid precipitated from the filtrate as sulphate of baryta, ignited and weighed. The residue was detached from the filter, mixed with carbonate and nitrate of potash, and fused in a gold crucible. The fused mass was dissolved in hydrochloric acid, evaporated to dryness, moistened with strong acid, diluted and filtered. From the filtrate the sulphuric acid was precipitated as sulphate of baryta, and from this the sulphur was calculated. It seems always to have occurred as iron pyrites ($Fe\ S_2$) in the ore. In tabulating the results accordingly, the iron required to combine with this sulphur was subtracted from the percentage of insoluble residue, as well as from the composition of that residue. It may be here noted, that when finely divided iron pyrites is boiled with strong hydrochloric acid and perchloride of iron, some of the latter is reduced and some sulphuric acid formed. It is important to remember this in the analysis of hæmatites.

13. *Phosphoric acid.*—A weighed portion of the ore was digested in hydrochloric acid, and the solution filtered. The filtrate was heated, (the iron reduced by sulphite of soda when necessary,) nearly neutralized with carbonate of soda, and excess of acetate of soda added. The liquid was boiled, and perchloride of iron added, drop by drop, to the hot solution, till the precipitate had a decidedly red colour. The precipitate was collected on a filter, washed with hot water, dissolved in hydrochloric acid, tartaric acid added, and, finally, excess of ammonia. The phosphoric acid was precipitated by addition of the mixture of sulphate of magnesia, chloride of ammonium, and free ammonia, 24 hours being allowed for the precipitate to separate. It was then collected on a filter, dissolved in hydrochloric acid, and some tartaric acid added to the solution. The phosphate was re-precipitated by ammonia,

collected on a filter, ignited, moistened with a few drops of nitric acid, re-ignited, and weighed.

14. *Water.*—A portion of the ore was weighed out, dried in the water oven, and re-weighed to determine hygroscopic water. It was transferred to a tube closed at one end; the other end was then connected by a cork to a small weighed tube containing chloride of calcium. Heat was applied to the tube containing the powder, and gradually increased to low redness. The majority of the ores suffer decomposition during this, with evolution of a gas arising from the decomposition of carbonates, which prevents, in most cases, the necessity of drawing any air through the apparatus. The tube containing chloride of calcium was then re-weighed to ascertain the amount of chemically combined water. In clay ironstones this is combined with the silicate of alumina or clay which they contain in admixture.

15. *Carbonic acid.*—The single flask apparatus was used; sulphuric acid was employed to decompose the carbonates in the ore.

16. *Metals precipitable by sulphuretted hydrogen from the hydrochloric acid solution.*—A weighed portion of the ore, varying from 200 or 300 grs. to 2,000 grs. was digested for a long time in hydrochloric acid. The solution was filtered off (the iron in the filtrate reduced, when necessary, by sulphite of soda), and a current of sulphuretted hydrogen passed through it. A small quantity of sulphur which always separated was collected on a filter and thoroughly washed. It was incinerated at as low a temperature as possible. The residue was mixed with carbonate of soda, and heated upon charcoal before the blowpipe; and any globules of metal obtained were dissolved and tested.

Sometimes the portion insoluble in hydrochloric acid was re-digested in hydrochloric acid and chlorate of potash added from time to time. The solution was then filtered off, and added to the original solution before reduction of persalts of iron.

Details of Method No. II.—A weighed portion of the ore was digested in hydrochloric acid, and the liquid filtered. The insoluble matter was fused as in Method No. I., dissolved in hydrochloric acid, and added to the original solution. The mixture was then evaporated to dryness to obtain the silica. In other respects the method of analysis was precisely similar to that described as No. I., avoiding only that part referring to the separate treatment of the matter insoluble in hydrochloric acid.

Details of Method No. III.—This method, owing to its greater simplicity and accuracy, was the one ultimately adopted. A weighed portion of the ore was digested in hydrochloric acid, and the liquid filtered. The insoluble matter was ignited, weighed, and treated in a manner precisely similar to that described under Method No. I.

2. The iron in the hydrochloric acid solution was peroxidized when necessary. The solution was heated, nearly neutralized with ammonia, then boiled with excess of acetate of ammonia, and filtered whilst hot. The precipitate was washed with hot water. The filtrate was received in a flask, and rendered alkaline by ammonia; a few drops of bromine were added, and the flask was tightly corked, to exclude air, and left 24 hours. The liquid was then heated, and rapidly filtered; the precipitate was ignited, and weighed, as $Mn^3 O^4$. The lime and magnesia contained in the filtrate were determined as in Method No. I. It may be here noted, that the ammonio-phosphate of magnesia obtained by this process is never mixed with any phosphate of alumina, owing to the alumina being completely precipitated as basic acetate.

3. The precipitated basic acetates (2) were dissolved in hydrochloric acid. The solution was supersaturated with caustic potash, boiled in a platinum basin, and filtered. The alumina containing some phosphoric acid was precipitated from the filtrate as in Method No. I. The phosphoric acid was separated by the tartaric acid process; the ammonio-phosphate of magnesia was always re-dissolved and re-precipitated, but still was seldom quite pure, containing generally a little silicate of alumina. Another determination was always made. It was ascertained that when this method was employed no phosphoric acid remained with the iron after treatment with potash. A little silica, however, did remain, but the quantity was small, and as nothing further was done with the iron after treatment with potash, this was lost from the analysis, a more accurate method for the determination of the iron being employed.

4. *Iron.*—Two determinations were always made by Dr. Penny's very accurate volumetrical process. The burette employed was graduated to cubic millimetres. Pure zinc was used to reduce the iron before adding the standard solution. When the ore contained both oxides of iron, precautions were taken to prevent the action of the air on the solution whilst the ore was dissolving.

5. All the other ingredients of the ore were determined in the manner described under Method No. I.

In all cases the actual weights of the substances obtained during the analysis have been given, so that corrections may be made should the atomic weights at present in use be altered at any future time. The atomic weights which have been employed are the same as those in the edition of Fownes' Chemistry, published in 1854, except in the cases of manganese and magnesium. The former of these has always been taken as 28·00; the latter, in the analysis by A. Dick, as 12·36.

Experiments on the Determination of Peroxide and Protoxide of Iron when they exist together in an Ore.—Extremely unsatisfactory results having been obtained by the use of Fuchs' process, some experiments were made with weighed quantities of the pure materials. The copper used was electrotype copper; the iron was in the state of peroxide prepared by precipitation and ignition. The hydrochloric acid was of known strength. The experiments were made in stoppered bottles filled by the liquid to exclude the air.

4·17 grs. of peroxide of iron were dissolved in twice the amount of acid required for complete solution, and poured into a stoppered bottle, containing a piece of sheet copper presenting about 3 square inches of surface. The stopper was tied down with caoutchouc, and the whole left at the ordinary temperature till the solution became nearly colourless. About 16 days were required. The copper was then washed, first with a hot solution of common salt, and afterwards with pure water. It had lost 3·26 grs., whereas it ought to have lost 3·29 had the whole of the produced chloride of copper been converted into dichloride. The bulk of the liquid was about an ounce and a quarter. Similar experiments with twice and ten times the amount of acid above yielded like results; as also did an experiment in which 30 grs. of chloride of sodium were used instead of excess of acid to dissolve the dichloride as it formed.

Similar experiments were made at 100° C. with like results, only that the change, which at the ordinary temperature takes many days, is effected in a few hours.

3·39 grs. of peroxide of iron, dissolved in twice the amount of acid requisite for solution, were treated exactly as above, except that the bottle was kept in a bath at 100° C. The solution became colourless in a few hours, and the copper was found to have lost 2·74 grs., whereas it ought to have lost 2·68 grs. A similar experiment

in which five times the requisite amount of acid was employed, and another in which 20 grs. of chloride of sodium were employed, instead of excess of acid, also yielded results which were nearly accurate. It was found, however, that when this process was applied to the analysis of the ores it sometimes did not yield such accurate results.

Marguerite's volumetric method was used once or twice, but laid aside in favour of Dr. Penny's, owing to the trouble of preparing the solution, and keeping it of known strength. The solution of bichromate of potash employed was much weaker than that employed by Dr. Penny. To show the accuracy of this process, some of the experiments which were made for the purpose of testing it are given. They are quoted without selection, being just in the order in which they were made. The iron employed was fine iron wire. Quantity taken 4·025; found 4·050: taken 2·90; found 2·91: taken 4·29; found 4·285: taken 6·51; found 6·505: taken 4·10; found 4·07: taken 5·35; found 5·37: taken 4·77; found 4·77 grs. The mean error of the 7 experiments was rather more than 0·01 gr. of iron.

Experiments on the Determination of Phosphoric Acid.

To determine the accuracy of the process proposed by Fresenius, for separating phosphoric acid from iron and alumina by means of tartaric acid.

10·67 grs. of phosphate of baryta, prepared by adding ordinary tribasic phosphate of soda to chloride of barium and igniting the precipitate, were dissolved in hydrochloric acid. Excess of sulphuric acid was added to the solution, which was filtered, and the precipitate found to weigh 11·14 grs.

About 8 grs. of peroxide of iron, and 3 of alumina, both free from phosphoric acid, were dissolved in hydrochloric acid, and added to the filtrate. Tartaric acid and excess of ammonia were then added, and the phosphoric acid precipitated as ammonio-phosphate of magnesia. It was allowed 24 hours to separate, then collected on a filter, and washed with ammonia water. As it still contained some iron, it was re-dissolved, and re-precipitated by ammonia, after addition of some tartaric acid, about 24 hours being allowed in this as in all following experiments, for its separation. Weight of pyrophosphate of magnesia 5·35 grs.

Operated upon.	Calculated.	Found.
10·67 grs. of phosphate of baryta=	7·26 grs. of baryta.	7·32 grs.
	3·41 grs. of phosphoric acid.	3·41 grs.

This shows the accuracy of the process when the iron is not in very large excess.

To determine whether the process is equally accurate when a minute quantity of phosphoric acid has to be separated from a large quantity of iron, or of salts necessarily introduced during the process.

The source of phosphoric acid was a solution of ordinary tribasic phosphate of soda preserved in a stoppered bottle to prevent alteration.

Two determinations of the strength of the solution were made. In the first 130·43 grs. of solution yielded 1·515 grs. of pyrophosphate of magnesia. In the second, 336·25 grs. yielded 3·88 grs. of pyrophosphate of magnesia. Therefore 100 grs. of solution contained 0·74 gr. of phosphoric acid, by both experiments.

Effect of chloride of ammonium.—79·25 grs. of solution were diluted to about 5 ounces, and 400 grs. of chloride of ammonium added. The phosphoric acid was

precipitated as before. Weight of pyrophosphate of magnesia 0·92 grs., equivalent to 0·74 grs. per cent. of phosphoric acid in solution. Chloride of ammonium, therefore, does not affect the accuracy of the process.

Effect of nitrate of ammonia.—94·07 grs. of solution were added to half an ounce of strong nitric acid supersaturated with ammonia. The phosphoric acid was precipitated as before, the bulk of the liquid being about 3 ounces. Weight of pyrophosphate of magnesia 1·105 grs., equivalent to 0·74 gr. per cent. of phosphoric acid. Nitrate of ammonia, therefore, does not affect the accuracy of the process.

Effect of tartrate of ammonia.—135·15 grs. of solution were added to a solution of 150 grs. of tartaric acid. The whole was supersaturated with ammonia, and the phosphoric acid precipitated as before. Weight of pyrophosphate of magnesia 1·55 grs., equivalent to 0·73 gr. per cent. of phosphoric acid. Tartrate of ammonia, therefore, does not affect the accuracy of the process.

It may here be observed that these salts, though they do not prevent the ultimate complete precipitation, exert an effect on the appearance of the precipitate. If to a solution of phosphoric acid a mixture of sulphate of magnesia, ammonia, and just as much chloride of ammonium as will prevent the precipitation of hydrate of magnesia be added, the ammonio-phosphate of magnesia separates at once and almost entirely (which may be proved by filtering a portion, and leaving the filtrate to stand) as a bulky gelatinous precipitate. In the course of a few days the precipitate assumes a crystalline appearance. The addition of salts of ammonia accelerates this change so much that it may be made to take place in a few minutes. No other salt of the alkalies (such as chloride of sodium), which has been tried, acts in the same manner. If, instead of precipitating the ammonio-phosphate of magnesia from a liquid containing little ammoniacal salts, it be precipitated from one containing a large quantity, the precipitate appears very slowly, is highly crystalline, and adheres strongly to the sides of the vessel.

Effect of sulphate of magnesia.—85·33 grs. of solution were mixed with 20 grs. of sulphate of magnesia, and 40 grs. of chloride of ammonium, and the phosphoric acid precipitated as before. Weight of ammonio-phosphate of magnesia 1·05 grs. equivalent to 0·78 gr. per cent. of phosphoric acid.

In another experiment, made under nearly the same conditions, 97·65 grs. of solution were employed, and 1·18 grs. of pyrophosphate of magnesia obtained, equivalent to 0·77 gr. per cent. of phosphoric acid.

In another experiment 65·95 grs. of solution were mixed with 30 grs. of sulphate of magnesia and an equal quantity of chloride of ammonium. The phosphoric acid was precipitated as before. The precipitate was washed with extreme care. Weight of pyrophosphate of magnesia 0·79 gr., equivalent to 0·76 gr. per cent. of phosphoric acid. The slight excess in these three results is probably owing to the enclosure of a little of the mother liquid between the particles of the crystals, which it is difficult to remove by washing, and which leaves a fixed residue on calcination; but as the ammonio-phosphate of magnesia was, in the following analysis, never thrown down from a liquid containing so much fixed salt, and was, moreover, invariably re-dissolved and re-precipitated before ignition, no error can arise from this cause.

Effect of the solution of peroxide of iron in tartaric acid and ammonia.—18·68 grs. of solution were added to a liquid containing about 70 or 80 grs. of peroxide of iron, tartaric acid, and excess of ammonia. To this a mixture of sulphate of magnesia, chloride of ammonium, and free ammonia was added, and the whole left for three

days. It was then filtered, the precipitate dissolved and re-precipitated, tartaric acid having been added to the solution as usual. Weight of pyrophosphate of magnesia 0·14 gr., equivalent to 0·47 gr. per cent. of phosphoric acid. To corroborate this result, another experiment was made.

39·01 grs. of solution were mixed with an amount of the liquid containing tartaric acid, ammonia, and iron, still greater than in the preceding experiment. The mixture of sulphate of magnesia, chloride of ammonium, and free ammonia, was then added, and the whole left for some days, at the end of which time no precipitate had appeared. More free ammonia and magnesian mixture were then added, and the whole left 24 hours more. Still no precipitate separated. A few drops more of the solution containing phosphoric acid were added, and left 24 hours longer, but still no precipitate formed. This could not be explained by the bulk of the liquid, which was not greater than in some previous experiments, in which the mixture of tartaric acid, iron, and ammonia was not present, but must have to be due to a power possessed by this mixture to retain a small quantity of ammonio-phosphate of magnesia in solution.

To prove the accuracy of the process described at page 49.—95·14 grs. of solution were added to a liquid containing about 60 grs. of iron, free from phosphoric acid. The iron was in the state of protoxide; a little of it was then peroxidized, and the solution nearly neutralized with carbonate of soda; excess of acetate of soda was added, and the liquid was boiled and filtered. The red coloured precipitate was collected on a filter, and dissolved in hydrochloric acid; tartaric acid and excess of ammonia were added to the solution, and the phosphoric acid was precipitated as ammonio-phosphate of magnesia, 24 hours being allowed for its separation. It was collected on a filter, dissolved in hydrochloric acid, and re-precipitated by ammonia from a solution containing some tartaric acid. Weight of pyrophosphate of magnesia 1·10 grs. equivalent to 0·735 per cent. phosphoric acid.

20·68 grs. of solution were treated in exactly the same manner as the above. Weight of pyrophosphate of magnesia 0·24 gr., equivalent to 0·80 per cent. of phosphoric acid. It must be remembered that this determination being made on about 20 grs. of solution, the error, in calculating to 100, becomes magnified 5 times.

In a mineral consisting in great part of phosphoric acid, the considerable quantity of iron required to precipitate this as perphosphate, might ultimately be sufficient to retain a little of the ammonio-phosphate of magnesia in solution; but as the iron ores contain only a comparatively small amount of phosphoric acid, there is no fear of any appreciable error on this account.

Separation of phosphoric acid from alumina.—To test the accuracy of Fuchs' method of separating phosphoric acid from alumina by silicate of potash, the following experiment was made:—5·31 grs. of phosphate of baryta, from the same sample as that alluded to at page 52, was dissolved in hydrochloric acid; sulphuric acid was added to the solution, which was then filtered. Some alumina, free from phosphoric acid, was dissolved in hydrochloric acid, and the solution added to the filtrate, which was then supersaturated with caustic potash. Excess of a solution of silica in caustic potash was added, and a bulky precipitate which separated collected on a filter and washed. The filtrate was acidified with hydrochloric acid, and supersaturated with ammonia to precipitate excess of silica as far as possible. The liquid was filtered off, concentrated, and the mixture of sulphate of magnesia, chloride of ammonium, and free ammonia added. This occasioned the formation of a bulky precipitate, in part flocculent, in part crystalline. The whole was

acidified with hydrochloric acid, which dissolved the crystalline and left the flocculent part of the precipitate. The liquid was filtered off, supersaturated with ammonia, and left 24 hours. The ammonio-phosphate of magnesia which separated was highly crystalline. It was ignited, and found to weigh 2·69 grs., equivalent to 1·71 of phosphoric acid, the calculated quantity being 1·70. None of the precipitates were analyzed. It would seem, therefore, that the process is an accurate one.

The method proposed by Rose for the determination of phosphoric acid was tried by J. Spiller, and found to give accurate results, but was not adopted in the subsequent analyses of the ores on account of its being more tedious than the process already described. Rose's process depends upon the conversion of the phosphoric acid into a basic phosphate of suboxide of mercury (by treating the nitric acid solution of the phosphate with mercury, in quantity more than sufficient to dissolve completely), and the decomposition of this by fusion with an alkaline carbonate. The phosphoric acid in the phosphate so formed is then precipitated by a mixed solution of sulphate of magnesia, chloride of ammonium, and ammonia, and weighed in the form of pyrophosphate of magnesia as usual. In the actual experiment a phosphate of baryta, containing 27·37 per cent. of phosphoric acid gave by this process 26·85 per cent. showing a loss, therefore, of 0·52 of phosphoric acid.

I.—Weardale Ore (West Level). (By J. Spiller.)

Towlaw Iron Works, Durham.

Description.—An altered spathose ore, in which the greater part of the carbonate of iron has been converted into hydrated peroxide, which in many places still shows the structure of the original ore. The portions which are undecomposed occur in irregular nodule-like forms of a pale brownish gray colour; these are surrounded by a mass varying from crystalline to earthy, of which the colour is from a snuff brown to a dark purplish brown. The streak varies with the colour from yellowish to reddish brown.

A small quantity of fluorspar was attached to one side of the specimen, but was not included in the portion selected for analysis.

Analysis by Method No. III.

Water, hygroscopic, and total amount.	grs.
I. 27·02 grains of ore lost of water at 100° C. - - -	0·49
II. 62·72 „ „ - - -	1·155
I. 55·215 grs. of ore gave of water at a red heat - -	4·635
II. 26·93 „ „ - - -	2·275

By the action of hydrochloric acid:

	grs.
13·77 grs. of ore gave of—	
Insoluble residue	0·95
Manganoso-manganic oxide ($Mn_3 O_4$)	0·43
Peroxide of iron (containing 0·04 gr. of silica)	8·58
Alumina	0·06
Sulphate of lime	1·89
Pyrophosphate of magnesia	0·55
69·80 grs. of ore gave of—	
Sulphate of baryta (resulting from sulphates in the hydrochloric acid solution)	trace.
Insoluble residue	4·815
which being fused, gave of—	
Silica	4·435
Alumina	0·285
Peroxide of iron	0·05
Sulphate of lime	0·015
Pyrophosphate of magnesia	0·03
The insoluble residue from 48·69 grs. of ore gave of—	
Organic matter	trace.
Sulphate of potash	0·045
Phosphoric acid and sulphur as pyrites:	
100·77 grs. of ore gave of—	
Pyrophosphate of magnesia	0·015
Sulphate of baryta	0·12
I. 48·235 grs. of ore gave of carbonic acid	6·99
II. 32·91 „ „	4·84
Determinations repeated:	
16·845 grs. of ore gave of—	
Manganoso-manganic oxide ($Mn_3 O_4$)	0·555
Sulphate of lime	2·325
Pyrophosphate of magnesia	0·565
Alumina and peroxide of iron (containing 0·05 gr. of silica)	10·40

Iron, by standard solutions of bichromate and permanganate of potash:—

Standard: 1 grain of iron = 9·03 cub. cent. of bichromate of potash solution.
1 grain of iron = 9·15 cub. cent. of permanganate of potash solution

Iron, total amount.

By bichromate of potash:

Weight of ore.	Cub. cent. of solution.	Per cent. iron.
I. 9·665	37·5	42·97
II. 9·255	36·0	43·07

By permanganate of potash:

Weight of ore.	Cub. cent. of solution.	Per cent. iron.
III. 5·31	20·9	43·01
IV. 10·04	39·2	42·67

Iron, existing in the state of protoxide.

By bichromate of potash:

	Weight of ore.	Cub. cent. of solution.	Per cent. iron.
I.	18·85	14·2	8·34
II.	33·55	25·5	8·41

By permanganate of potash:

	Weight of ore.	Cub. cent. of solution.	Per cent. iron.
III.	26·46	20·8	8·59
IV.	28·37	22·4	8·63

Results tabulated.

	I.	II.
Peroxide of iron - -	49·50	
Protoxide of iron - -	10·77	
Protoxide of manganese -	3·06	2·90
Alumina - - -	0·43	
Lime - - -	5·68	5·66
Magnesia - - -	1·20	1·42
Silica - - -	0·29	0·29
Carbonic acid - -	14·49	14·70
Phosphoric acid - -	0·01	
Sulphuric acid - -	trace.	
Bisulphide of iron - -	0·03	
Water, hygroscopic -	1·81	8·40
,, in combination -	6·63	
Organic matter - -	trace.	
Insoluble residue - -	6·90	6·90
	100·80	

Insoluble Residue.

Silica - - -	6·35
Alumina - - -	0·41
Peroxide of iron - -	0·07
Lime - - - -	0·01
Magnesia - - -	0·01
Potash - -	0·05
	6·90

Iron, total amount - 43·02

A trace of lead was found in 400 grains of the ore,

II.—Weardale Ore, Rispey. (By A. Dick.)

Description.—Spathose ore; easily scratched by the file; lustre, semi-vitreous; colour, yellowish gray; streak, white; fracture, crystalline: some portions are much darker than others. When a mass of the ore is digested in hydrochloric acid till all carbonates are dissolved, there remains a skeleton of quartz, having the shape and size of the original mass, containing casts of the crystals which have been dissolved. The dark coloured parts of the ore leave a dark skeleton, which, when exposed to the vapour of hydrofluoric acid till all silica is removed, leaves a small amount of matter, having a dark gray colour. When this is washed with hydrochloric acid and water there remains a very small amount of black matter, which burns when heated in the air, and leaves no residue. It is therefore carbonaceous matter.

Analysis by Method No. III.

Water, total amount.

33·07 grs. of ore lost at 100° C. 0·02. Above 100° C. 0·08.

By the action of hydrochloric acid:

13·10 grs. of ore gave of insoluble residue	0·50
Manganoso-manganic oxide	0·34
Alumina	trace.
Carbonate of lime	0·82
(Above converted into sulphate of lime	1·10)
Pyrophosphate of magnesia	1 13
3·35 grs. of insoluble matter gave of silica	3·32
Alumina containing a trace of iron	006

Phosphoric and sulphuric acids, and bisulphide of iron.

64·95 grs. of ore gave of—	
Pyrophosphate of magnesia	trace.
70·30 grs. of ore gave of—	
Sulphate of baryta (from sulphates)	trace.
Sulphate of baryta (from bisulphide of iron)	0·20
I. 39·59 grs. of ore gave of carbonic acid	14·92
II. 24·25 grs. of ore gave of carbonic acid	9·10

Iron by standard solution of bichromate of potash.

Standard: 1 grain of iron = 8·45 cub. cent. of solution.

Weight of ore.	Cub. cent. of solution.	Per cent. of iron.
8·37	27·3	38·56

Several other determinations of iron were made with a solution of bichromate of potash of different standard. They all agree closely with the above; none being more than 0·20 per cent. different.

All the iron occurs in the state of protoxide.

41·61 grs. of ore gave no alkalies, and only a trace of organic matter.

The silica obtained from the iron in the hydrochloric acid solution was, by one determination, as much as 1·20 per cent.; by another, only 0·62 per cent. This separation, as has been said, never being complete, can never be constant, but is seldom so great as this.

Results tabulated.—Ore dried above 100° C.

Protoxide of iron (mean of 5 determinations)	49·47
Protoxide of manganese	2·42
Alumina	trace.
Lime	3·47
Magnesia	3·15
Carbonic acid (mean of 2 determinations)	37·71
Phosphoric acid	trace.
Silica, by one determination 0·62, by another	1·20
Sulphuric acid	trace.
Bisulphide of iron	0·08
Organic matter	trace.
Insoluble matter, by one determination 3·89	3·77
	101·27

Insoluble Residue.

Silica	3·73
Alumina containing trace of iron	0·06
	3·79

Iron, total amount	38·56

No metal, precipitable by sulphuretted hydrogen from the hydrochloric acid solution of 1000 grs. of ore, was detected.

III.—Cleator Moor Hæmatite. (By A. Dick.)

(Nos. 424 and 426 of the Illustrated Catalogue.)

Description, No. 424.—Compact red hæmatite; easily scratched by a file; lustre, earthy; colour, purplish gray; streak, bright red; fracture, uneven, showing cavities lined with crystals of specular iron, and containing, in some cases, quartz.

No. 426 resembles 424. It is harder, being scarcely scratched by a file, more lustrous, and darker in colour; the cavities contain more quartz, but the substance of the ore seems purer.

The sample analyzed was composed of a mixture of the two.

Analysis by Method No. III.

Water, total amount.	grs.
21·61 grs. of ore lost on ignition	0·10
By the action of hydrochloric acid:	
23·16 grs. of ore gave of—	
Insoluble residue	1·315
Manganoso-manganic oxide	0·06
Alumina	trace.
Sulphate of lime	0·04
7·905 of insoluble residue gave of—	
Silica	7·87
Alumina containing a trace of iron	0·08
Phosphoric and sulphuric acids, and bisulphide of iron.	
108·90 grs. of ore gave of—	
Pyrophosphate of magnesia	trace.
31·00 grs. of ore gave of—	
Sulphate of baryta (from sulphates)	trace.
5·81 grs. of residue gave of—	
Sulphate of baryta (from bisulphide of iron)	trace.

Iron, by standard solution of bichromate of potash.

Standard: 1 grain of iron = 8·45 cub. cent. of solution.

Weight of ore.	Cub. cent. of solution.	Per cent. of iron.
I. 8·765	49·2	66·73
II. 7·22	40·4	66·50

All the iron occurred in the state of peroxide of iron. Before adding the standard solution, the perchloride of iron was reduced by sulphite of soda. When this is used as the reducing agent the result is apt to be too high, owing to the difficulty of expelling the last traces of sulphurous acid. For this reason zinc was almost invariably used as the reducing agent.

Results tabulated.—Ore dried above 100° C.

Peroxide of iron - - -	95·16
Protoxide of manganese - - -	0·24
Lime - - - -	0·07
Phosphoric acid - - -	trace.
Sulphuric acid - - -	trace.
Bisulphide of iron - -	trace.
Insoluble residue - - -	5·68
	101·15

Insoluble Residue.

Silica - - - -	5·66
Alumina, containing a trace of iron -	0·06
	5·72
Iron, total amount - - -	66·60

A most minute trace of lead was detected in 400 grs. of ore.

IV.—Cleator Moor Iron Ore. (By A. Dick.)

(Nos. 427 and 429, Illustrated Catalogue.)

Description, No. 427.—Compact red hæmatite; easily scratched by a file; lustre, earthy; colour, deep red-gray; streak, bright red; fracture, uneven, showing numerous cavities lined with microscopic crystals. This ore does not contain quartz visibly diffused through it.

No. 429.—Composed of a mixture of small pieces of compact hard red ore and a powdery variety of hæmatite. This latter is unctuous, more lustrous, and redder in colour than the compact variety. The sample analyzed was composed of a mixture of the two.

Analysis by Method No. III.

Water total amount.	grs.
27·91 grs. of the ore lost on ignition - -	0·19
By the action of hydrochloric acid 13·42 grs. of ore gave of—	
Insoluble residue - - - -	1·145
Manganoso-manganic oxide - - -	0·015
Alumina - - - - - -	0·05
Sulphate of lime - - - -	0·23
Pyrophosphate of magnesia - - -	0·02
9·025 grs. of insoluble residue gave of	
Silica - - - - - -	7·44
Alumina - - - - -	1·12
Peroxide of iron - - - - -	0·25
Lime - - - - - -	trace.
Phosphoric and sulphuric acids, and bisulphide of iron.	
114·80 grs. of ore gave of—	
Pyrophosphate of magnesia - - -	trace.
31·00 grs. of ore gave of—	
Sulphate of baryta (from sulphates) - -	trace.
26·08 grs. of insoluble residue gave of—	
Sulphate of baryta (from bisulphide of iron)	0·64

Iron by standard solution of bichromate of potash.

Standard: 1 grain of iron = 8·45 cub. cent. of solution.

Weight of ore.	Cub. cent. of solution.	Per cent of iron.
I. 6·14 grs.	32·7	63·44
II. 7·93 grs.	42·0	63·06

All the iron occurred in the state of peroxide.

Tabulated Results.—Ore dried above 100° C.

Peroxide of iron - - -	90·36
Protoxide of manganese - -	0·10
Alumina - - - -	0·37
Lime - - - -	0·71
Magnesia - - - -	0·06
Phosphoric acid - - -	trace.
Sulphuric acid - - -	trace.
Bisulphide of iron - -	0·06
Insoluble residue - - -	8·54
	100·20

Insoluble Residue.

Silica - - - -	7·05
Alumina - - -	1·06
Peroxide of iron - - -	0·19
Lime - - - -	trace.
	8·30
Iron, total amount - - -	63·25

A trace of lead was detected in 500 grs. of ore.

V.—Gillbrow Ore, Ulverstone. (By A. Dick.)

Description.—Red hæmatite; unctuous; easily scratched by the file; lustre, sub-metallic; colour, purplish red; streak, bright red; fracture, uneven and minutely crystalline; pieces of carbonate of lime and other minerals occur in it, which, getting coloured by the powder, cannot be seen until the specimen is washed.

Analysis by Method No. III.

Water, total amount.
20·85 grs. of ore lost at 100° C. 0·70.
And gave 0·12 grs. more water by heating to redness.
By the action of hydrochloric acid—

	grs.
9·09 grs. of ore gave of—	
Insoluble residue - - -	0·57
Manganoso-manganic oxide -	0·02
Sulphate of lime - - -	0·585
Pyrophosphate of magnesia - -	0·35
2·21 grs. of insoluble residue gave of—	
Silica - - - -	2·085
Alumina - - -	0·11

Phosphoric and sulphuric acids, and bisulphide of iron.
114·90 grs. of ore gave only a trace of pyrophosphate of magnesia.

	grs.
36·19 grs. of ore gave of sulphate of baryta - -	0·11

Bisulphide of iron was not sought for, as the residue did not contain a weighable quantity of iron.

34·03 grs. of ore gave of carbonic acid - - -	0·97

Iron by standard solution of bichromate of potash.

Standard: 1 grain of iron = 8·45 cub. cent. of solution.

Weight of ore.	Cub. cent. of solution.	Per cent. of iron.
I. 7·40	36·4	60·56
II. 9·295	45·7	60·55

All the iron exists in the state of peroxide.

Results tabulated.—Ore dried above 100° C.

Peroxide of iron - - -	86·50
Protoxide of manganese - -	0·21
Lime - - - -	2·77
Magnesia - - - -	1·46
Carbonic acid - - -	2.96
Phosphoric acid - - -	trace.
Sulphuric acid - - -	0·11
Insoluble residue - - -	6·55
	100·56

Insoluble Residue.

Silica - - - -	6·18
Alumina, containing a trace of iron -	0·30
	6·48

Iron, total amount - - -	60·55

A whitish metal, precipitable by sulphuretted hydrogen from the hydrochloric acid solution, was found. The quantity obtained from 500 grs. of ore was so small that it could not be identified.

VI.—Hæmatite, Lindale Moor, near Ulverstone, Lancashire. (By J. Spiller.)

The sample was selected from a large quantity of the ore, consisting of fragments of various degrees of hardness, the majority of which were of the hard compact variety, deep grayish purple in colour, and covered with a brownish red unctuous powder; there were also small quantities of fibrous hæmatite and specular iron, together with quartz and a little earthy matter.

Analysis by Method No. III.

Water, hygroscopic.	grs.
33·66 grs. of ore lost of water at 100° C. - -	0·13
Water, total amount.	
20·325 grs. of ore lost on ignition - - -	0·115
By the action of hydrochloric acid :	
7·80 grs. of ore gave of—	
Insoluble residue - - - -	0·42
Manganoso-manganic oxide (Mn_3O_4) - -	0·02
Alumina - - - - -	0·04
44·28 grs. of ore gave of—	
Sulphate of lime - - - -	0·055
Pyrophosphate of magnesia - -	0·01
17·165 grs. of ore gave of—	
Insoluble residue - - - - - -	0·89
Which being fused, yielded of—	
Silica - - - - -	0·83
Alumina - - - - -	0·02
Peroxide of iron } Oxalate of lime } - - -	traces.
Phosphoric and sulphuric acids, and bisulphide of iron.	
54·865 grs. of ore gave of—	
Pyrophosphate of magnesia	a minute trace.
Sulphate of baryta (from sulphates) - -	0·145
Sulphate of baryta (from bisulphide of iron) -	0·07

Iron by standard solution of bichromate of potash.

Standard: 1 gr. of iron = 8·45 cub. cent. of solution.

Weight of ore.	Cub. cent. of solution.	Per cent. iron.
I. 4·915	27·4	65·96
II. 5·075	28·3	65·99

All the iron exists in the state of peroxide.

Results tabulated.

Peroxide of iron - -	94·23—94·27
Protoxide of manganese - -	0·23
Alumina - - -	0·51
Lime - - - -	0·05
Magnesia - - -	trace.
Phosphoric acid - -	minute trace.
Sulphuric acid - - -	0·09
Bisulphide of iron - -	0·03
Water, hygroscopic - -	0·39
,, combined - - -	0·17
Insoluble residue - - -	5·18
	100·88

Insoluble Residue.

Silica - - -	4·90
Alumina - - - -	0·12
Peroxide of iron, Lime - - -	traces.
	5·02

Iron, total amount - -	65·98

A distinct trace of arsenic was detected in 1680 grs. of ore.

VII.—White Bed Mine, Bierley, Yorkshire.

(By J. Spiller.)

(Nos. 300 to 304 of the Illustrated Catalogue.)

Clay ironstones, of varying colour, from a light brown gray to black gray, the shades deepening in intensity with the order of the numbers. Nos. 302 and 303 show a conchoidal fracture, have a closer texture, and are harder than the

others. No. 304 has a rough surface of fracture. A vein of iron pyrites occurs in No. 302; and is the cause of the somewhat large proportion of that substance described in the analysis.

The sample analyzed consisted of equal weights of the several ores.

Analysis by Method No. III.

Water, hygroscopic, and total amount.	grs.
34·38 grs. of ore lost of water at 100° C.	0·255
14·60 grs. of ore yielded of water at a red heat	0·27
By the action of hydrochloric acid:	
21·22 grs. of ore gave of—	
Insoluble residue	5·94
Manganoso-manganic oxide ($Mn_3 O_4$)	0·215
Alumina	0·17
Sulphate of lime	1·435
Pyrophosphate of magnesia	1·32
The insoluble residue gave by analysis—	
Silica	4·06
Alumina	1·45
Peroxide of iron	0·12
Sulphate of lime	0·055
Pyrophosphate of magnesia	0·04
34·38 grs. of ore gave of—	
Organic matter	0·08
Chloride of potassium	0·43
25·70 grs. of ore gave of carbonic acid	6·53
Phosphoric and sulphuric acids, and bisulphide of iron:	
55·36 grs. of ore gave of—	
Sulphate of baryta (from sulphates)	trace.
Sulphate of baryta (from bisulphide of iron)	0·40
Pyrophosphate of magnesia	0·415

Iron by standard solution of bichromate of potash.

(Standard: 1 gr. of iron = 8·45 cub. cent. of solution.)

Iron, total amount.

	Weight of ore.	Cub. cent. of solution.	Per cent. iron.
I.	10·55	25·2	28·26
II.	9·77	23·5	28·46
Iron, in the state of protoxide.			
III.	8·43	19·6	27·52

Results tabulated.

Protoxide of iron	35·38
Peroxide of iron	1·20
Protoxide of manganese	0·94
Alumina	0·80
Lime	2·78
Magnesia	2·22
Carbonic acid	25·41
Phosphoric acid	0·48
Sulphuric acid	trace.
Bisulphide of iron	0·18
Water, hygroscopic	0·74
,, combined	1·11
Organic matter	0·23
Insoluble residue	28·00
	99·47

Insoluble Residue.

Silica	19·13
Alumina	6·83
Peroxide of iron	0·57
Lime	0·11
Magnesia	0·07
Potash	0·78
	27·49
Iron, total amount	28·76

A distinct trace of copper was detected in 500 grains of the ore.

VIII.—Black Bed Mine, Low Moor, Yorkshire.

(By J. Spiller.)

(Nos. 305 to 310 of the Illustrated Catalogue.)

All are dark blackish gray clay ironstones, particularly Nos. 309 and 310. The two latter are easily scratched by a steel point, the rest being much harder; fracture, Nos. 305, 306, 307, 308 compact, showing a tendency to the conchoidal in Nos. 305 and 308; that of 309 and 310, rough and irregular. No. 308 contains iron pyrites in the form of exceedingly fine films taking the outline of shells.

The ores were mixed in the proportion of equal weights to procure the sample for analysis.

Analysis by Method No. III.

	grs.
Water, hygroscopic, and combined.	
27·98 grs. of ore lost of water at 100° C.	0·17
And yielded of water at a red heat	0·325
By the action of hydrochloric acid:	
26·20 grs. of ore gave of—	
Insoluble residue	6·62
Manganoso-manganic oxide (Mn_3O_4)	0·39
Alumina	0·135
Sulphate of lime	1·72
Pyrophosphate of magnesia	1·505
The insoluble residue gave of—	
Silica	4·55
Alumina	1·63
Peroxide of iron	0·22
Oxalate of lime	trace.
Pyrophosphate of magnesia	0·09
41·20 grs. of ore gave of—	
Organic matter	0·99
Chloride of potassium	0·43
Phosphoric and sulphuric acids, and bisulphide of iron.	
74·90 grs. of ore gave of—	
Pyrophosphate of magnesia	0·405
Sulphate of baryta (from sulphates)	trace.
Sulphate of baryta (from bisulphide of iron)	0·29
32·97 grs. of ore gave of carbonic acid	8·76
Iron by standard solution of bichromate of potash.	
Standard: 1 gr. of iron = 8·45 cub. cent. of solution.	

Iron, total amount.

	Weight of ore.	Cub. cent. of solution.	Per cent. iron.
I.	10·64	25·7	28·58
II.	10·85	26·1	28·50

Iron, as protoxide.

III.	11·115	26·5	28·11

Results tabulated.

Protoxide of iron - - -	36·14
Peroxide of iron - - -	0·61
Protoxide of manganese - -	1·38
Alumina - - - -	0·52
Lime - - - -	2·70
Magnesia - - - -	2·05
Carbonic acid - - - -	26·57
Phosphoric acid - - -	0·34
Sulphuric acid - - - -	trace.
Bisulphide of iron - - -	0·10
Water, hygroscopic - - -	0·61
,, combined - - -	1·16
Organic matter - - -	2·40
Insoluble residue - - -	25·27
	99·85

Insoluble Residue.

Silica - - - -	17·37
Alumina - - -	6·22
Peroxide of iron - - -	0·84
Lime - - - -	trace.
Magnesia - - - -	0·12
Potash - - - - -	0·65
	25·20

Iron, total amount - - -	29·12

None of the metals, precipitable by sulphuretted hydrogen from the hydrochloric acid solution, were found in 600 grains of ore.

IX.—Thorncliffe or Old Black Mine, Parkgate, Yorkshire. (By J. Spiller.)

(Nos. 320 and 321 of the Illustrated Catalogue.)

Clay Ironstones, No. 320.—Colour, dark brownish gray; easily scratched by a steel point; fracture, compact and slightly conchoidal. The ore is abundantly seamed by cracks of contraction filled with carbonate of lime, iron, &c. (brown spar). No. 321 has a brown gray colour; same hardness as 320; fracture, rough and irregular. It contains impressions of rootlets of stigmaria.

The sample analyzed consisted of equal weights of each ore.

Analysis by Method No. III.

	grs.
Water, hygroscopic, and total amount.	
26·515 grs. of ore lost of water at 100° C.	0·145
19·765 grs. of ore yielded of water at red heat	0·335
By the action of hydrochloric acid:	
25·63 grs. of ore gave of—	
Insoluble residue	3·63
Manganoso-manganic oxide (Mn_3O_4)	0·31
Alumina	0·15
Sulphate of lime	1·59
Pyrophosphate of magnesia	2·665
The insoluble residue gave of—	
Silica	2·29
Alumina	1·08
Peroxide of iron	0·11
Oxalate of lime	trace.
Pyrophosphate of magnesia	0·105
37·48 grs. of ore gave of—	
Organic matter	0·325
Chloride of potassium	0·25
Phosphoric and sulphuric acids, and bisulphide of iron.	
40·74 grs. of ore gave of—	
Pyrophosphate of magnesia	0·48
Sulphate of baryta (from sulphates)	traces.
Sulphate of baryta (from bisulphide of iron)	
33·29 grs. of ore gave of carbonic acid	10·45

Iron by standard solution of bichromate of potash.

Standard: 1 gr. of iron = 8·45 cub. cent. of solution.

Iron, total amount.

Weight of ore.	Cub. cent. of solution.	Per cent. iron.
I. 9·095	26.0	33·83
II. 9·20	26·35	33·89

Iron, as protoxide.

I. 13·925	38·1	32·38
II. 8·855	24·4	32·61

Results tabulated.

Protoxide of iron	41·77
Peroxide of iron	1·96
Protoxide of manganese	1·13
Alumina	0·58
Lime	2·55
Magnesia	3·71
Carbonic acid	31·39
Phosphoric acid	0·75
Sulphuric acid } Bisulphide of iron }	traces.
Water, hygroscopic	0·55
„ in combination	1·15
Organic matter	0·86
Insoluble residue	14·16
	100·56

Insoluble Residue.

Silica	8·93
Alumina	4·21
Peroxide of iron	0·43
Lime	trace.
Magnesia	0·14
Potash	0·43
	14·14

Iron, total amount - - - - 34·16

None of the metals, precipitable by sulphuretted hydrogen from the hydrochloric acid solution, were found in 500 grs. of ore.

X.—Thorncliffe White Mine, Parkgate, Yorkshire.

(By J. Spiller.)

(Nos. 322, 323 *a* and *b*, of the Illustrated Catalogue.)

Clay Ironstones, No. 322.—Light brownish gray in colour; easily scratched by a steel point; fracture, rough, with a slight tendency to the conchoidal. Nos. 323 *a* and *b* are very similar in appearance; their colour is a darker brownish gray than 322, and much harder. Texture, very compact, and fracture, conchoidal. No. 323 *a* has small veins of sulphate of baryta and carbonate of lime, with a trace of pyrites.

The sample analyzed consisted of equal weights of the three ores.

Analysis by Method No. III.

Water, hygroscopic and combined.	grs.
21·93 grs. of ore lost of water at 100° C.	0·15
Same portion of ore yielded of water at a red heat	0·31
By the action of hydrochloric acid:	
30·92 grs. of ore gave of—	
Insoluble residue	5·985
Manganoso-manganic oxide (Mn_3O_4)	0·315
Alumina	0·255
Sulphate of lime	1·70
Pyrophosphate of magnesia	3·225
The insoluble residue gave of—	
Silica	3·76
Alumina	1·73
Peroxide of iron	0·14
Oxalate of lime	trace.
Pyrophosphate of magnesia	0·15
Sulphate of baryta	trace.
41·52 grs. of ore gave of—	
Organic matter	0·225
Chloride of potassium	0·245
Phosphoric and sulphuric acids, and bisulphide of iron.	
56·96 grs. of ore gave of—	
Pyrophosphate of magnesia	0·42
Sulphate of baryta (as such in the ore) Sulphate of baryta (from bisulphide of iron	traces.
35·86 grs. of ore gave of carbonic acid	10·535

Iron by standard solution of bichromate of potash.

Standard: 1 gr. of iron = 8·45 cub. cent. of solution.

Iron, total amount.

	Weight of ore.	Cub. cent. of solution.	Per cent. iron.
I.	13·31	35·5	31·56
II.	13·435	35·7	31·45

Iron, as protoxide.

III.	10·47	27·1	30·63

Results tabulated.

Protoxide of iron	39·38
Peroxide of iron	1·24
Protoxide of manganese	0·95
Alumina	0·82
Lime	2·26
Magnesia	3·72
Carbonic acid	29·38
Phosphoric acid	0·47
Sulphate of baryta, Bisulphide of iron	traces.
Water, hygroscopic	0·68
,, in combination	1·41
Organic matter	0·54
Insoluble residue	19·35
	100·20

Insoluble Residue.

Silica	12·16
Alumina	5·60
Peroxide of iron	0·45
Lime	trace.
Magnesia	0·17
Potash	0·37
	18·75

Iron, total amount	31·82

A minute trace of copper was detected in 450 grains of the ore.

XI.—Black or Clay Wood Mine, Parkgate, Yorkshire.

(By J. Spiller.)

(No. 326 of the Illustrated Catalogue.)

A dark grayish black clay ironstone, having some very small particles of pyrites sparingly diffused through it. Tolerably hard; the surface of fracture minutely granular.

Analysis by Method No. III.

	grs.
Water, hygroscopic.	
51·03 grs. of ore lost of water at 100° C.	0·30
Water, total amount.	
29·175 grs. of ore yielded of water at a red heat	0·525
By the action of hydrochloric acid:	
18·18 grs. of ore gave of—	
Insoluble residue	3·69
Manganoso-manganic oxide (Mn_3O_4)	0·27
Alumina	0·135
Sulphate of lime	0·935
Pyrophosphate of magnesia	1·345
The analysis of the insoluble residue gave of—	
Silica	2·455
Alumina	0·98
Peroxide of iron	0·14
Oxalate of lime	trace.
Pyrophosphate of magnesia	0·07
39·15 grs. of ore gave of—	
Organic matter	0·325
Chloride of potassium	0·11
Phosphoric and sulphuric acids, and bisulphide of iron.	
51·03 grs. of ore gave of—	
Pyrophosphate of magnesia	0·545
Sulphate of baryta (from sulphates)	0·02
Sulphate of baryta (from bisulphide of iron)	0·10
22·13 grs. of ore gave of carbonic acid	6·30

Iron by standard solution of bichromate of potash.

Standard: 1 gr. of iron = 8·45 cub. cent. of solution.

	Weight of ore.	Cub. cent. of solution.	Per cent. iron.
Iron, total amount.			
I.	9·47	25·1	31·36
II.	10·82	28·7	31·39
Iron, existing as protoxide.			
III.	11·755	30·8	31·01

Results tabulated.

Protoxide of iron	39·87
Peroxide of iron	0·53
Protoxide of manganese	1·38
Alumina	0·74
Lime	2·12
Magnesia	2·64
Carbonic acid	28·47
Phosphoric acid	0·69
Sulphuric acid	trace.
Bisulphide of iron	0·05
Water, hygroscopic	0·59
„ combined	1·21
Organic matter	0·83
Insoluble residue	20·30
	99·42

Insoluble Residue.

Silica	13·50
Alumina	5·39
Peroxide of iron	0·77
Lime	trace.
Magnesia	0·13
Potash	0·18
	19·97
Iron, total amount	31·92

Traces of lead and copper were detected in 680 grains of the ore.

XII.—Swallow-wood Rake, Stanton, Derbyshire.*
(By J. Spiller.)

(Nos. 335, 336, and 337 of the Illustrated Catalogue.)

Clay Ironstones.—Easily scratched; Nos 336 and 337, light drab in colour; No. 335, a shade darker. All have a rough, non-crystalline fracture, and are readily reduced to powder, especially 337.

The sample analyzed consisted of equal weights of each ore.

Analysis by Method No. III.

Water, hygroscopic.	grs.
50·255 grs. of ore lost of water at 100° C.	0·29
Water, total amount.	
22·50 grs. of ore gave of water at a red heat	0·325
By the action of hydrochloric acid:	
21·51 grs. of ore gave of—	
Insoluble residue	5·065
Manganoso-manganic oxide (Mn_3O_4)	0·235
Alumina	0·145
Sulphate of lime	2·085
Pyrophosphate of magnesia	3·27
The analysis of the insoluble residue yielded of—	
Silica	3·445
Alumina	1·235
Peroxide of iron	0·17
Oxalate of lime	trace.
Pyrophosphate of magnesia	0·035
53·78 grs. of ore gave of—	
Organic matter	0·19
Chloride of potassium	0·40
Phosphoric and sulphuric acids, and bisulphide of iron.	
50·255 grs. of ore gave of—	
Pyrophosphate of magnesia	0·335
Sulphate of baryta (derived from sulphates)	trace.
Sulphate of baryta (from bisulphide of iron)	0·26
16·50 grs. of ore gave of carbonic acid	4·725

Iron by standard solution of bichromate of potash.

Standard: 1 gr. of iron = 8·45 cub. cent. of solution.

Weight of ore.	Cub. cent. of solution.	Per cent. iron.
I. 12·11	26·7	26·09
II. 10·33	22·9	26·23

Hydrochloric acid does not extract any appreciable amount of peroxide of iron from the ore; all this iron exists, therefore, in the state of protoxide.

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* For the position of this ore, see Yorkshire Section, p. 35.

Results tabulated.

Protoxide of iron	33·72
Protoxide of manganese	1·01
Alumina	0·67
Lime	3·99
Magnesia	5·43
Carbonic acid	28·64
Phosphoric acid	0·41
Sulphuric acid	trace.
Bisulphide of iron	0·13
Water, hygroscopic	0·57
„ in combination	0·87
Organic matter	0·36
Insoluble residue	23·55
	99·35

Insoluble Residue.

Silica	16·02
Alumina	5·74
Peroxide of iron	0·79
Lime	trace.
Magnesia	0·06
Potash	0·47
	23·08
Iron, total amount	26·79

None of the metals, precipitable by sulphuretted hydrogen from the hydrochloric acid solution, were detected in 560 grains of ore.

XIII.—Brown Rake, Butterley, Derbyshire.
(By J. Spiller.)
(Nos. 344 and 345 of the Illustrated Catalogue.)

Clay Ironstones, No. 344.—Colour, pale brownish gray, inclining to red in some parts from peroxidation; very thin seams of a blueish shale are irregularly interstratified with the ore; fracture, unusually rough. No. 345; colour, blackish gray, of various degrees of intensity in irregular bands parallel to the plane of stratification. The ore contains an abundance of fossil shells incrusted with ochrey peroxide of iron.

A mixture of equal weights of the two ores was taken for analysis.

Analysis by Method No. III.

	grs.
Water, hygroscopic.	
31·49 grs. of ore lost of water at 100° C.	0·235
Water, total amount.	
15·82 grs. of ore yielded of water at a red heat	0·35
By the action of hydrochloric acid:	
18·775 grs. of ore gave of—	
Insoluble residue	3·07
Manganoso-manganic oxide (Mn_3O_4)	0·305
Alumina	0·08
Sulphate of lime	2·065
Pyrophosphate of magnesia	1·735
The insoluble residue gave by analysis—	
Silica	1·885
Alumina	0·97
Peroxide of iron	0·085
Sulphate of lime	0·03
Pyrophosphate of magnesia	0·04
40·76 grs. of ore gave of—	
Organic matter	0·58
Chloride of potassium	0·36
Phosphoric and sulphuric acids, and bisulphide of iron.	
47·27 grs. of ore gave of—	
Sulphate of baryta (from sulphates)	trace.
Sulphate of baryta (from bisulphide of iron)	0·105
Pyrophosphate of magnesia	0·585
19·10 grs. of ore yielded of carbonic acid	5·715
Iron by standard solution of bichromate of potash.	
Standard: 1 gr. of iron = 8·45 cub. cent. of solution.	

Iron, total amount.

	Weight of ore.	Cub. cent. of solution.	Per cent. iron.
I.	10·22	26·2	30·33
II.	9·315	23·8	30·24

Iron, in the state of protoxide.

I.	10·02	25·0	29·52
II.	10·80	27·0	29·58

Results tabulated.

Protoxide of iron - - -	37·99
Peroxide of iron - - -	1·04
Protoxide of manganese - -	1·51
Alumina - - -	0·41
Lime - - - -	4·53
Magnesia - - - -	3·30
Carbonic acid - - -	29·92
Phosphoric acid - - -	0·80
Sulphuric acid - - -	trace.
Bisulphide of iron - - -	0·06
Water, hygroscopic - -	0·74
,, in combination - -	1·47
Organic matter - - -	1·42
Insoluble residue - - -	16·35
	99·54

Insoluble Residue.

Silica - - - -	10·04
Alumina - - - -	5·16
Peroxide of iron - - -	0·45
Lime - - - -	0·06
Magnesia - - - -	0·07
Potash - - - -	0·55
	16·33

Iron, total amount - - - 30·60

A trace of reddish metal, too small to examine, was detected in 1200 grains of the ore.

XIV.—Brown Rake, Butterley, Derbyshire.

(By J. Spiller.)

(No. 346 of the Illustrated Catalogue.)

Clay Ironstone. — Slightly peroxidized throughout, brownish gray in colour; easily scratched by a steel point; fracture, rough and perfectly devoid of crystalline structure.

Analysis by Method No. III.

		grs.
Water, hygroscopic.		
30·60 grs. of ore lost of water at 100° C.	- - -	0·21
Water, total amount.		
16·80 grs. of ore yielded of water at a red heat	- -	0·365
By the action of hydrochloric acid:		
22·715 grs. of ore gave of—		
Insoluble residue	- - - - -	5·64
Manganoso-manganic oxide ($Mn_3\ O_4$)	- -	0·30
Alumina	- - - - - -	0·105
Sulphate of lime	- - - - -	1·62
Pyrophosphate of magnesia	- - -	1·72
The insoluble residue gave by analysis—		
Silica	- - - - - -	3·65
Alumina	- - - - - -	1·505
Peroxide of iron	- - - -	0·21
Sulphate of lime	- - - - -	0·04
Pyrophosphate of magnesia	- - -	0·165
44·70 grs. of ore gave of—		
Organic matter	- - - - -	0·34
Chloride of potassium	- - -	0·47
Phosphoric and sulphuric acids, and bisulphide of iron.		
42·965 grs. of ore gave of—		
Sulphate of baryta (from sulphates)	- -	not weighable.
Sulphate of baryta (from bisulphide of iron)	-	0·08
Pyrophosphate of magnesia	- - - -	0·44
24·025 grs. of ore gave of carbonic acid	- - -	6·425

Iron by standard solution of bichromate of potash.

Standard: 1 gr. of iron = 8·45 cub. cent. of solution.

Iron, total amount.

	Weight of ore.	Cub. cent. of solution.	Per cent. iron.
I.	11·615	28·1	28·63
II.	7·70	18·7	28·74

Iron, existing in the state of protoxide.

	Weight of ore.	Cub. cent. of solution.	Per cent. iron.
I.	9·09	21·3	27·73
II.	10·145	23·9	27·87

Results tabulated.

Protoxide of iron - - -	35·74
Peroxide of iron - -	1·26
Protoxide of manganese - -	1·23
Alumina - - -	0·47
Lime - - -	2·94
Magnesia - - -	2·70
Carbonic acid - - - -	26·74
Phosphoric acid - -	0·66
Sulphuric acid - - -	trace.
Bisulphide of iron - - -	0·05
Water, hygroscopic - - -	0·68
" combined - -	1·49
Organic matter - - -	0·76
Insoluble residue - - - -	24·83
	99·56

Insoluble Residue.

Silica - - - -	16·07
Alumina - - - -	6·62
Peroxide of iron - - -	0·92
Lime - - - -	0·07
Magnesia - - - -	0·26
Potash - - -	0·66
	24·60
Iron, total amount of - - -	29·32

Distinct traces of lead and copper were found in 600 grains of ore.

XV.—Black Rake, Butterley, Derbyshire.

(By J. Spiller.)

(Nos. 347 and 348 of the Illustrated Catalogue.)

Clay Ironstones, No. 347.—Colour, dark gray; somewhat hard; fracture, irregular; structure, compact. The ore contains thin films of pyrites disposed in the form of shells. No. 348, a darker coloured carbonaceous ore, having a rough surface of fracture; easily pulverized.

The sample analyzed consisted of equal weights of the two ores.

Analysis by Method No. III.

	grs.
Water, hygroscopic.	
35·635 grs. of ore lost of water at 100° C. - -	0·265
Water, total amount.	
19·07 grs. of ore yielded of water at a red heat - -	0·43
By the action of hydrochloric acid:	
20·37 grs. of ore gave of—	
Insoluble residue - - - - -	5·39
Manganoso-manganic oxide (Mn_3O_4) -	0·21
Alumina - - - - - -	0·15
Sulphate of lime - - - - -	1·495
Pyrophosphate of magnesia - - -	1·605
The insoluble residue by its analysis gave of—	
Silica - - - - - -	3·49
Alumina - - - - - -	1·58
Peroxide of iron - - -	0·10
Sulphate of lime - - - - -	0·07
Pyrophosphate of magnesia - - -	0·145
39·79 grs. of ore gave of—	
Organic matter - - - - -	0·625
Chloride of potassium - - - -	0·47
Phosphoric and sulphuric acids, and bisulphide of iron.	
32·84 grs. of ore gave of—	
Sulphate of baryta (from sulphates) - -	trace.
Sulphate of baryta (from bisulphide of iron) -	0·33
Pyrophosphate of magnesia - -	0·405
30·275 grs. of ore gave of carbonic acid - -	7·76

Iron by standard solution of bichromate of potash.

Standard: 1 gr. of iron = 8·45 cub. cent. of solution.

	Weight of ore.	Cub. cent. of solution.	Per cent. iron.
Iron, total amount.			
I.	8·65	19·9	27·23
II.	10·405	24·0	27·29
Iron, as protoxide.			
III.	9·885	21·8	26·10

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Results tabulated.

Protoxide of iron	33·56
Peroxide of iron	1·66
Protoxide of manganese	0·96
Alumina	0·73
Lime	3·02
Magnesia	2·81
Carbonic acid	25·63
Phosphoric acid	0·79
Sulphuric acid	trace.
Bisulphide of iron	0·26
Water, hygroscopic	0·74
,, combined	1·51
Organic matter	1·57
Insoluble residue	26·46
	99·70

Insoluble Residue.

Silica	17·13
Alumina	7·76
Peroxide of iron	0·50
Lime	0·15
Magnesia	0·25
Potash	0·74
	26·53
Iron, total amount	27·61

Distinct traces of copper and lead were found in 700 grains of ore.

XVI.—Dog-tooth Rake, Staveley, Derbyshire.

(By J. Spiller.)

(Nos. 352, 353, and 355 of the Illustrated Catalogue.)

Clay Ironstones.—All of the same colour, light brownish gray; rough in fracture; easily scratched by a steel point. No. 353 contains a few shells irregularly diffused.

The sample analyzed consisted of equal weights of each ore.

Analysis by Method No. III.

Water, hygroscopic.	grs.
39·135 grs. of ore lost of water at 100° C.	0·25
Water, total amount.	
23·85 grs. of ore yielded of water at a red heat	0·395
By the action of hydrochloric acid:	
26·05 grs. of ore gave of—	
Insoluble residue	4·975
Manganoso-manganic oxide ($Mn_3 O_4$)	0·305
Alumina	0·10
Sulphate of lime	1·00
Pyrophosphate of magnesia	3·37
The insoluble residue gave by its analysis—	
Silica	3·10
Alumina	1·445
Peroxide of iron	0·155
Sulphate of lime	0·025
Pyrophosphate of magnesia	0·145
47·51 grs. of ore gave of—	
Organic matter	0·145
Chloride of potassium	0·505
Phosphoric and sulphuric acids, and bisulphide of iron.	
39·84 grs. of ore gave of—	
Sulphate of baryta (from sulphates)	not weighable.
Sulphate of baryta (from bisulphide of iron)	0·07
Pyrophosphate of magnesia	0·30
29·15 grs. of ore gave of carbonic acid	8·785

Iron, by standard solution of bichromate of potash.

Standard: 1 gr. of iron = 8·45 cub. cent. of solution.

Weight of ore.	Cub. cent. of solution.	Per cent. iron.
Iron, total amount.		
I. 9·105	23·8	30·94
II. 10·645	27·8	30·91
Iron, in the state of protoxide.		
III. 12·30	31·5	30·31

Results tabulated.

Protoxide of iron	38·97
Peroxide of iron	0·88
Protoxide of manganese	1·09
Alumina	0·38
Lime	1·58
Magnesia	4·62
Carbonic acid	30·14
Phosphoric acid	0·48
Sulphuric acid	trace.
Bisulphide of iron	0·05
Water, hygroscopic	0·64
,, in combination	1·02
Organic matter	0·30
Insoluble residue	19·10
	99·25

Insoluble Residue.

Silica	11·90
Alumina	5·55
Peroxide of iron	0·59
Lime	0·04
Magnesia	0·20
Potash	0·67
	18·95

Iron, total amount	31·34

A minute trace of copper was found in 630 grains of ore.

XVII.—Dog-tooth Rake, Staveley, Derbyshire.

(By J. Spiller.)

(Nos. 354 and 356 of the Illustrated Catalogue.)

Clay Ironstones.—Both light brownish gray in colour, and containing abundance of fossil shells, which in the case of No. 354 are large and confusedly packed together, though generally lying parallel to the plane of stratification; but in No. 356 occur as a more irregular deposit, made up in part, apparently, of fragments of shells. The hardness of the ores is such that they are not easily scratched by a steel point; fracture, compact and irregular, the surface of fracture being influenced by the position of the contained shells.

The sample analyzed consisted of a mixture of the two ores in equal weights.

Analysis by Method No. III.

	grs.
Water, hygroscopic.	
27·30 grs. of ore lost of water at 100° C.	0·05
Water, in combination.	
Same portion of ore yielded of water at a red heat	0·20
By the action of hydrochloric acid:	
18·14 grs. of ore gave of—	
Insoluble residue	1·16
Manganoso-manganic oxide ($Mn_3 O_4$)	0·20
Alumina	0·06
Sulphate of lime	6·145
Pyrophosphate of magnesia	4·665
The insoluble residue gave by analysis—	
Silica	0·645
Alumina	0·36
Peroxide of iron	0·075
Oxalate of lime	trace.
Pyrophosphate of magnesia	0·045
44·61 grs. of ore gave of—	
Organic matter	0·41
Chloride of potassium	0·115
Phosphoric and sulphuric acids, and bisulphide of iron.	
44·48 grs. of ore gave of—	
Sulphate of baryta (from sulphates)	trace.
Sulphate of baryta (from bisulphide of iron)	0·075
Pyrophosphate of magnesia	0·515
24·99 grs. of ore gave of carbonic acid	9·40

Iron, by standard solution of bichromate of potash.
Standard: 1 gr. of iron = 8·45 cub. cent. of solution.

Iron, total amount.

	Weight of ore.	Cub. cent. of solution.	Per cent. iron.
I.	8·44	16·2	22·71
II.	10·22	19·6	22·69

Iron, existing as protoxide.

I.	9·755	18·2	22·08
II.	13·19	24·4	21·90

Results tabulated.

Protoxide of iron	28·27
Peroxide of iron	1·01
Protoxide of manganese	1·02
Alumina	0·33
Lime	13·94
Magnesia	9·18
Carbonic acid	37·61
Phosphoric acid	0·74
Sulphuric acid	trace.
Bisulphide of iron	0·04
Water, hygroscopic	0·18
,, in combination	0·73
Organic matter	0·92
Insoluble residue	6·39
	100·36

Insoluble Residue.

Silica	3·55
Alumina	1·98
Peroxide of iron	0·41
Lime	trace.
Magnesia	0·09
Potash	0·16
	6·19

Iron, total amount	22·98

A minute trace of a white metal, too small to examine, was found in 460 grains of the ore.

XVIII.—Honeycroft Rake, Stanton, Derbyshire.

(By J. Spiller.)

(Nos. 387 to 394 of the Illustrated Catalogue.)

Clay Ironstones.—Colour, Nos. 389 and 394, blackish gray; the others, brownish gray; hardness, the two just mentioned are easily scratched by a steel point; the others not so readily; surface of fracture, rough and irregular in Nos. 389 and 394; the rest are compact, and show a tendency to the conchoidal fracture, especially No. 392 No. 393 contains fossil shells, but not in great number; 391 very few; No. 388 has cracks of contraction filled with carbonate of iron, lime, &c. (brown spar); some shells and zinc blende.

The sample taken for analysis consisted of equal weights of the several ores.

Analysis by Method No. III.

Water, hygroscopic and combined.	grs.
24·06 grs. of ore lost of water at 100° C.	0·11
Same portion of ore yielded of water at a red heat	0·27
By the action of hydrochloric acid:	
25·505 grs. of ore gave of—	
Insoluble residue	4·55
Manganoso-manganic oxide (Mn_3O_4)	0·345
Alumina	0·15
Sulphate of lime	1·725
Pyrophosphate of magnesia	2·055
The insoluble residue gave of—	
Silica	2·855
Alumina	1·36
Peroxide of iron	0·18
Oxalate of lime	trace.
Pyrophosphate of magnesia	0·12
40·95 grs. of ore gave of—	
Organic matter	0·565
Chloride of potassium	0·22
Phosphoric and sulphuric acids, and bisulphide of iron.	
42·86 grs. of ore gave of—	
Pyrophosphate of magnesia	0·225
Sulphate of baryta (from sulphates)	trace.
Sulphate of baryta (from bisulphide of iron)	0·155
31·995 grs. of ore gave of carbonic acid	9·51

Iron by standard solution of bichromate of potash.

Standard: 1 gr. of iron = 8·45 cub. cent. of solution.

Iron, total amount.

	Weight of ore.	Cub. cent. of solution.	Per cent. iron.
I.	8·63	23·5	32·22
II.	9·795	26·7	32·26
Iron, as protoxide.			
III.	9·545	25·1	31·12

Results tabulated.

Protoxide of iron	40·01
Peroxide of iron	1·60
Protoxide of manganese	1·26
Alumina	0·58
Lime	2·78
Magnesia	2·88
Carbonic acid	29·72
Phosphoric acid	0·34
Sulphuric acid	trace.
Bisulphide of iron	0·09
Water, hygroscopic	0·45
„ combined	1·12
Organic matter	1·38
Insoluble residue	17·84
	100·05

Insoluble Residue.

Silica	11·19
Alumina	5·33
Peroxide of iron	0·70
Lime	trace.
Magnesia	0·17
Potash	0·34
	17·73

Iron, total amount - - - 32·73

A minute trace of copper was detected in 480 grains of ore.

XIX.—Civilly Rake, Stanton, Derbyshire.

(By J. Spiller.)

(Nos. 395 to 399 of the Illustrated Catalogue.)

Clay Ironstones.—Colour, No. 399, brown gray; all the others are dark blackish gray; hardness, Nos. 395, 397, 398, are easily scratched by a steel point, the other two are sensibly harder. The fractured surface is compact in Nos. 396 and 399; rough and irregular in the others. No. 396 exhibits internal cracks filled with pink sulphate of baryta, with a little carbonate of lime and zinc blende. The central part of the stone, where effected by these cracks, is altered in colour, apparently by peroxidation.

A mixture of equal weights of the several ores was taken for analysis.

Analysis by Method No. III.

Water, hygroscopic.	grs.
20·90 grs. of ore lost of water at 100° C. - -	0·145
Water, total amount.	
23·36 grs. of ore yielded of water at a red heat - -	0·60
By the action of hydrochloric acid:	
28·395 grs. of ore gave of—	
Insoluble residue - - - - -	7·785
Manganoso-manganic oxide ($Mn_3 O_4$) - -	0·665
Alumina - - - - - -	0·27
Sulphate of lime - - - - -	1·60
Pyrophosphate of magnesia - - -	1·945
The insoluble residue gave of—	
Silica - - - - - -	4·885
Alumina - - - - -	2·245
Peroxide of iron - - - - -	0·345
Pyrophosphate of magnesia - - - -	0·22
Sulphate of baryta - - - - -	trace.
No lime was detected.	
35·95 grs. of ore gave of—	
Organic matter - - - - -	0·665
Chloride of potassium - - - -	0·28
Phosphoric and sulphuric acids, and bisulphide of iron.	
43·67 grs. of ore gave of—	
Pyrophosphate of magnesia - - -	0·425
Sulphate of baryta (from sulphates) - -	trace.
Sulphate of baryta (from bisulphide of iron) -	0·22
26·10 grs. of ore gave of carbonic acid - - -	6·48

Iron by standard solution of bichromate of potash.

Standard: 1 gr. of iron = 8·45 cub. cent. of solution.

Iron, total amount.

	Weight of ore.	Cub. cent. of solution.	Per cent. iron.
I.	9·42	21·5	27·01
II.	10·485	23·8	26·87
Iron, in the state of protoxide.			
III.	18·77	41·1	25·91

Results tabulated.

Protoxide of iron	33·31
Peroxide of iron	1·47
Protoxide of manganese	2·18
Alumina	0·95
Lime	2·32
Magnesia	2·44
Carbonic acid	24·83
Phosphoric acid	0·62
Sulphate of baryta	trace.
Bisulphide of iron	0·13
Water, hygroscopic	0·70
,, in combination	1·87
Organic matter	1·85
Insoluble residue	27·42
	100·09

Insoluble Residue.

Silica	17·24
Alumina	7·90
Peroxide of iron	1·22
Magnesia	0·27
Potash	0·49
	27·12

Iron, total amount	27·79

A minute trace of copper was detected in 500 grains of the ore.

XX.—Dale Moor Rake, Stanton, Derbyshire.

(By J. Spiller.)

(Nos. 400 to 404 of the Illustrated Catalogue.)

Clay Ironstones.—Similar in the character of hardness and quality of the fractured surface, all being easily scratched by a steel point, and presenting rough surfaces of fracture. Colour, No. 400, pale gray brown; No. 401, brown; Nos. 402, 403, 404, dark brownish gray. The colour of the streak is in all cases yellowish brown.

No. 400 contains impressions of vegetable remains, including many rootlets of stigmaria; also some fish scales.* The occurrence of these animal remains may probably account for the comparatively large amount of phosphoric acid obtained on analysis.

The sample selected for analysis was composed of equal weights of the several ores.

Analysis by Method No. III.

Water, hygroscopic, and total amount.	grs.
23·35 grs. of ore lost of water at 100° C. - -	0·12
20·26 grs. of ore yielded of water at a red heat - -	0·355
By the action of hydrochloric acid:	
26·365 grs. of ore gave of—	
Insoluble residue - - - - -	4·165
Manganoso-manganic oxide ($Mn_3 O_4$) - -	0·425
Alumina - - - - -	0·30
Sulphate of lime - - - - -	2·125
Pyrophosphate of magnesia - - - -	2·11
The insoluble residue gave by its analysis—	
Silica - - - - - -	2·695
Alumina - - - - - -	1·19

* There are several very perfect specimens of fossil fishes, enclosed in this ironstone, exhibited in the cases of the Museum. They were presented by S. H. Blackwell, Esq.

	grs.
Peroxide of iron	0·205
Sulphate of lime	0·035
Pyrophosphate of magnesia	0·025
35·20 grs. of ore gave of—	
Organic matter	0·40
Chloride of potassium	0·265

Phosphoric and sulphuric acids, and bisulphide of iron.

38·79 grs. of ore gave of—	
Pyrophosphate of magnesia	0·675
Sulphate of baryta (from sulphates)	trace.
Sulphate of baryta (from bisulphide of iron)	0·07
37·55 grs. of ore gave of carbonic acid	10·75

Iron, by standard solution of bichromate of potash.

Standard: 1 gr. of iron = 8·45 cub. cent. of solution.

Iron, total amount.

Weight of ore.	Cub. cent. of solution.	Per cent. iron.
I. 7·43	20·5	32·65
II. 8·88	24·5	32·66

Iron, in the state of protoxide.

I. 12·50	32·6	30·86
II. 9·84	25·5	30·67

Results tabulated.

Protoxide of iron	39·55
Peroxide of iron	2·71
Protoxide of manganese	1·50
Alumina	1·14
Lime	3·32
Magnesia	2·85
Carbonic acid	28·63
Phosphoric acid	1·12
Sulphuric acid	trace.
Bisulphide of iron	0·05
Water, hygroscopic	0·51
,, combined	1·24
Organic matter	1·14
Insoluble residue	15·80
	99·56

Insoluble Residue.

Silica - - - -	10·22
Alumina - - - -	4·51
Peroxide of iron - - -	0·78
Lime - - - -	0·06
Magnesia - - - -	0·03
Potash - - - - -	0·48
	16·08
Iron, total amount - - -	33·20

Zinc blende, and a distinct trace of copper, were found in the ore.

XXI.—Cleveland Ore.

(By A. Dick.)

Description.—Chiefly a carbonate of protoxide of iron; lustre, earthy; colour, greenish gray; streak, similar; fracture, uneven, showing here and there small cavities, some of which are filled with carbonate of lime. Throughout the ore are diffused irregularly a multitude of small oolitic concretions, together with small pieces of an earthy substance resembling the ore but lighter in colour. When a mass of this ore is digested in hydrochloric acid till all carbonates and soluble silicates are dissolved, there remains a residue having the form of the original mass of ore. It is extremely light, and falls to powder unless very carefully handled. It contains the oolitic concretions, or else skeletons of them, which dissolve completely in dilute caustic potash, showing them to be silica in a soluble state. Under the microscope some of them are seen to have a central nucleus of dark colour and irregular shape, but none of them present any indication of organic structure or radiated crystallization. If the residue, after having been digested in caustic potash, be washed by decantation, there remains a small number of microscopic crystals; some of these, which are white, are

quartz, and others, which are black and acutely pyramidal, consist chiefly of titanic acid. Professor Miller of Cambridge succeeded in measuring some of the angles of the crystals containing titanic acid, and found that they corresponded to similar angles in anatase. The green colour of the ore seems to be due to a silicate containing peroxide and protoxide of iron, but this could not be exactly determined because it was not found possible to dissolve out the carbonates without acting at the same time upon the silicate of iron.

Analysis by Method No. III.

Water, hygroscopic, and total amount.

82·64 grs. of ore lost 0·31 grs. at 100° C.

And gave 2·45 grs. more water by ignition.

By the action of highly dilute hydrochloric acid—

19·60 grs. of ore gave of—	grs.
Insoluble residue - - - - - -	0·34
Silica, which had dissolved in the acid - -	1·39
Peroxide of iron - - - - - -	9·35
Alumina, containing phosphoric acid - -	1·88
(Pyrophosphate of magnesia *from alumina* - -	0·54)
Manganoso-manganic oxide - - -	0·20
Sulphate of lime - - - - - -	3·53
Pyrophosphate of magnesia - - -	2·05
3·74 grs. of insoluble residue gave of—	
Silica, containing a little titanic acid - -	3·49
Alumina, containing a little peroxide of iron - -	0·24
Phosphoric and sulphuric acids, and bisulphide of iron.	
51·14 grs. of ore gave of—	
Pyrophosphate of magnesia - - -	1·50
39·43 grs. of ore gave of—	
Sulphate of baryta (from sulphates) - - -	trace.
The insoluble residue from 45·71 grs. of ore gave of—	
Sulphate of baryta (from bisulphide of iron) - -	0·21
32·35 grs. of ore gave of—	
Organic matter - - - - - -	trace.
Chloride of potassium - - - -	0·14
33·59 grs. of ore gave of—	
Carbonic acid - - - - -	7·65

Iron, by standard solution of permanganate of potash.

Iron, total amount.

	Weight of ore.	Cub. cent. of solution.	Per cent. iron.
	12·28	36·8	33·62
Iron, as protoxide.			
I.	12·30	34·0	31·01
II.	10·25	28·7	31·41
III.	16·47	45·2	30·89

Results tabulated.—Ore dried at 100° C.

Protoxide of iron	39·92
Peroxide of iron	3·60
Protoxide of manganese	0·95
Alumina	7·86
Lime	7·44
Magnesia	3·82
Potash	0·27
Carbonic acid	22·85
Phosphoric acid	1·86
Silica, soluble in hydrochloric acid	7·12
Sulphuric acid	trace.
Bisulphide of iron	0·11
Water, in combination	2·97
Organic matter	trace.
Insoluble residue (of which 0·98 is soluble in dilute caustic potash), and consists chiefly of oolitic concretions	1·64
	100·41
Iron, total amount	33·62

Insoluble Residue.

Silica	1·50
Alumina, with a trace of peroxide of iron	0·10
Titanic acid, about	0·03
Lime	trace.
	1·63

No metal precipitable by sulphuretted hydrogen from the hydrochloric acid solution of about 1200 grs. of ore was detected.

LONDON:
Printed by GEORGE E. EYRE and WILLIAM SPOTTISWOODE,
Printers to the Queen's most Excellent Majesty.
For Her Majesty's Stationery Office.

MEMOIRS

OF THE

GEOLOGICAL SURVEY

OF

GREAT BRITAIN,

AND OF THE

MUSEUM OF PRACTICAL GEOLOGY.

THE IRON ORES OF GREAT BRITAIN.

PART II.

THE IRON ORES OF SOUTH STAFFORDSHIRE.

PUBLISHED BY ORDER OF THE LORDS COMMISSIONERS OF
HER MAJESTY'S TREASURY.

LONDON:
PRINTED FOR HER MAJESTY'S STATIONERY OFFICE.
PUBLISHED BY
LONGMAN, BROWN, GREEN, LONGMANS, AND ROBERTS.

1858.

In issuing the Second Part of the Memoir on the Iron Ores of Great Britain, comprising those of South Staffordshire, it is necessary to explain that, although the analyses have long been prepared, it became essential to the completion of the work, that Mr. Jukes should revisit a district in which many new mining operations have laid open phenomena previously unknown; but the onerous duties of Mr. Jukes in Ireland as Local Director of the Geological Society have hitherto interfered with his performance of this special duty. The Third Part of this Memoir will shortly appear.

RODERICK I. MURCHISON,
Director General.

November 1858.

CONTENTS.

PART II.

Iron Ores of the South Staffordshire Coal Field.

General Description. (By J. Beete Jukes, M.A., F.R.S.)

1. *External Appearance of the Iron District.*

A general account of the geology of the South Staffordshire coal field will be found in the Records of the School of Mines, vol. I., part 2., in which a description is given of the geological survey executed on part of the ordnance maps 62 N.W. and S.W. and 54 N.W. These maps were accompanied by 3 sheets of vertical sections, Nos. 16, 17, and 18, and three sheets of coloured longitudinal sections, Nos. 23, 24, and 25. The publication of the analyses of some of the iron ores of the district under the direction of Dr. Percy, at the instance and chiefly by the liberality of Mr. S. H. Blackwell, renders it advisable to make an abstract of the memoir mentioned above, with especial reference to the iron stones contained in the district.

The seat of the great iron manufacture of South Staffordshire is not co-extensive with the whole of that coal field, nor is it ever perhaps likely to become so, since it is the middle part only of the coal field which has ever been largely productive of ironstone. If we take the town of Dudley* as a centre, and draw a northern boundary line from Wolverhampton through Bloxwich to Walsall and a southern boundary line from Stourbridge to Halesowen, connecting Stourbridge with Wolverhampton on the west side, and Halesowen with Walsall on the east side, we shall include nearly the whole of the great iron-making area, great in results rather than in geographical extent. This area will

* Dudley is legally in Worcestershire, there being several large, and a multitude of small, isolated patches of Worcestershire which are enclosed within the boundaries of Staffordshire. One considerable piece of country around Halesowen is similarly reputed to be in Shropshire, though separated by many miles from any other part of that county.

approach in form to a parallelogram, 10 miles long from N.N.E. to W.S.W. and 5 miles wide from E. to W., containing therefore about 50 square miles.

There is hardly perhaps to be found anywhere in the world another space of 50 square miles of so peculiar a character. It is commonly known in the neighbourhood by the name of the " black country," an epithet the appropriateness of which must be acknowledged by every one who even passes through it on a railway.

Huge "spoil banks" of black shale, great mounds of rough slag and heaps of cinders and refuse of all descriptions, surround numbers of dark and massive smelting furnaces, puddling furnaces, rolling mills, and other huge structures for the smelting or the manufacture of iron. Flames and smoke are ceaselessly belched forth from their summits, while from their murky recesses break forth dazzling rays of light emitted by the surface of molten iron through half open furnace doors, or millions of brilliant sparks starting from glowing lumps at each blow of the forge hammer. Half naked figures may be seen trailing along fiery masses or passing them backwards and forwards between rollers which squeeze them, as if they were phosphorescent wax, into bars or rails or rods, or into thick wires spouting into the air and twining along the ground like snakes of fire.

Around these cyclopean dens are innumerable coal pits, with their engine houses and their creaking machinery for pumping and winding; large " coke hearths" with their smouldering heaps; and great stacks of coal and iron ready for transport along the net-work of canals and railways and tramways that ramify in every direction among them.

Quarries and " open works," sand pits, clay pits, and brick-kilns contribute to the apparent disorder of the scene; the surface of the earth seeming to be of use chiefly as a place whereon to manipulate the matters extracted from its interior.

Rows and clusters of small brick houses cover the whole country, connecting seven important towns* and sixteen large

* Wolverhampton, Bilston, Darlaston, Wednesbury, Walsall, Dudley, and Stourbridge.

villages which in other districts would be called towns,* so that in most cases it is not very easy to say where one town or village ends and another begins. The peculiarity of the scenery is increased by the occasional appearance of houses, and sometimes of large buildings and high chimneys, slanting considerably from the perpendicular, in consequence of the sinking in of the ground on which they stand, while the same cause produces unnatural-looking hollows, filled sometimes with shallow pools of water, spreading here and there over the surface. The canals and railroads for the same reason require constant watching, and frequent repairs and additions to their sides and embankments to keep them up to their original level. If we add to these strange features clouds of dense smoke and black dust, and imagine the perpetual creaking and clanking of chains and machinery, the panting and shrieking of steam engines, the continual thumping of forge hammers, and the everlasting bellowing of blast furnaces, we shall complete a picture calculated to astonish, if not perhaps to affright and disgust, the quiet inhabitant of a secluded rural district.

To the student of social or political science, however, to one who would anatomise the body politic and make himself acquainted with the structure of the hidden nerves and arteries, the muscles, bones, and sinews on which the strength and greatness of our country depends, such a district has an interest which soon overpowers this disgust. Nor should even the poet or the painter turn from it with disdain. It contains the elements of a certain kind of grandeur, if it be devoid of elegance or beauty. Let such an one witness the tapping of a smelting furnace on a winter's evening when the stream of liquid iron spreads into small glowing pools of fire, lighting up with an intense brilliancy the black masses of brickwork and snow-capped roofs around, and watch the play of light and shade and many tints of colour, as the white light from the molten iron changes into orange,

* Wednesfield, Bloxwich, Willenhall, Sedgley, Coseley, Tipton, Great Bridge, West Bromwich, Oldbury, Gornal, Netherton, Brierly Hill, The Lye, Cradley, Halesowen, and Rowley Regis.

and then slowly deepens into red. Or let him, after reading Milton's description of Pandemonium, take his stand on any of the eminences near Dudley, between six and eight o'clock of a clear dark night, and look over the surrounding country, lit up with fires and flames of every hue and every shade of brightness, fire beyond fire, over miles of ground on each side of him, and let him listen to the mingled hum and roar and shriek, that comes from near and far to his ears, and he will have presented to his senses a more close approach perhaps to a material representation of the poet's dream than any other spot of this earth can afford him.*

The cause of such an amount and such a concentration of mining and manufacturing industry within the small area mentioned above is the quantity of coal and ironstone to be found within a small vertical subterranean space, the top of that space being also within a very slight depth from the surface. Other coal fields may have beneath the surface a greater total amount of coal, and an equal or perhaps greater amount of ironstone. The beds of coal and ironstone, however, are generally separated from each other by a much greater thickness of other materials (clays, shales, sandstones, &c.) than in the South Staffordshire coal field, and there is thus rendered necessary either a much greater depth in each of the pits, or else a much wider diffusion of those pits over a larger area, in order to hit upon the different beds within a reasonable distance from the surface. In no other coal field of the United Kingdom is a thickness of 30 feet of coal to be found together, while in South Staffordshire 12 or 13 beds of coal rest one upon the other, with but very slight "partings" of shale between them, making up often that thickness and sometimes more.

* I once lived for some time on the borders of Staffordshire and Shropshire, about six miles from the nearest margin of this coal field, and between it and that of Coalbrokedale in Shropshire. On a dark winter's night, when the clouds were low, both quarters of the heavens were glowing red from the reflection of the fires beneath; and on a still frosty evening, from high ground, the noise of the machinery from the South Staffordshire district could be distinctly heard, something like the distant roar of carriages over a paved street, mingled with a low pulsation of forge hammers.

In the same way I believe the quantity of ironstone to be found in some parts of this district within a vertical space of 100 or 150 yards, is greater than is known anywhere else.

2. *Internal Structure of the South Staffordshire Coal Field.*

The following is a general account of all the beds known in the South Staffordshire coal field, beginning with the uppermost. It must not, however, be supposed that all these beds are to be found vertically one under the other in any one part even of that small area. The uppermost beds of all, are known only in its southern extremity, where the beds dip to the south. Deep sinkings show that the lowest beds are either altogether absent there, or at least no longer contain the coals and ironstones in which they are so rich a few miles farther north. Towards the north, on the other hand, the lower beds "crop out" or rise towards the surface, and it is therefore not possible that the upper beds should be found there. The following section, therefore, is compiled partly from the examination of the southern, partly of the middle, and partly of the northern part of the district, the object being to enumerate every important bed of coal and ironstone, and to show its place relatively to all the others that either do or might occur above and below it.

General Section of the Coal Measures in the South Staffordshire Coal Field.

	Feet.
Beds above the Upper Sulphur Coal - - -	500 to 600
*Upper Sulphur Coal - - - - - -	$1\frac{1}{2}$
Intermediate measures - - - -	about 140
*Little or Two-foot Coal - - - - - -	2
Intermediate measures - - -	varying from 2 to 48
1. Brooch Coal - - - - - -	about 4
I. Brooch Binds Ironstone measures - - - -	7 to 20
*Herring Coal - - - - - -	1

* These three coals are not numbered, because they have never been found in a sufficiently good condition to be worth working.

		Feet.
II.	Pins and Pennyearth Ironstone measures*	6 to 30
	Intermediate Measures, containing the Thick Coal Rock (a Sandstone)	38 to 157
III.†	Broad Earth, Catch Earth, and Batt, containing sometimes the Ten Foot and Backstone Ironstones	6 to 14
2.	Thick Coal	30
IV.	Pouncill Batt, Blacktery and Whitery, containing the Grains Ironstone and sometimes the Whitery Ironstone	2 to 8
V.	Gubbin Ironstone, sometimes called the Little or Top or Thick Coal Gubbin, sometimes the Black Ironstone	2 to 8
	Table Batt and intermediate measures	2 to 28
3.	Heathen Coal	about 3
	Intermediate measures (sometimes wanting)	0 to 43
4.	Rubble or Lower Heathen Coal, sometimes when the measures above are wanting, forming the bottom part of the Heathen Coal	2 to 4
	‡Intermediate measures	10 to 33
VI.	New Mine or White Ironstone	2 to 10
VII.	Measures containing Pennystone Ironstone, called also Bluestone or Cakes	10 to 25
5.	Sulphur Coal	2 to 9
	Intermediate measures	2 to 99
6.	New Mine Coal	2 to 11
VIII.	Measures containing the Fire-clay Balls Ironstone occasionally	2 to 40
7.	Fire-clay Coal	1 to 14
	Intermediate measures	2 to 10
IX.	Getting Rock Ironstone (occasional)	4 to 5
X.	Poor Robin Ironstone measures	3 to 5
	Intermediate measures	0 to 9
XI.	Rough Hills White Ironstone (occasional)	2 to 19
8.	Bottom Coal	3 to 12
	Intermediate measures	5 to 30
XII.	Gubbin and Balls Ironstone (or sometimes Bottom or Great Gubbin)	0 to 10
	Intermediate measures	18 to 50
9.	Singing or Mealy Grey Coal	2 to 4
	Intermediate measures	16 to 50
XIII.	Blue Flats Ironstone	2 to 9
	Intermediate measures	10 to 14
XIV.	Silver Threads Ironstone	4 to 7
	Intermediate measures	6 to 15
XV.	Diamonds Ironstone	2 to 3
	Lowest measures	0 to 50

* This measure is rich in the remains of fishes.

† Pronounced Broad Heath and Cat Heath.

‡ About Bentley there is a small ironstone, called Lambstone, 10 feet below the Heathen coal, and three feet under that again is an ironstone called the Brownstone, the total thickness between the Heathen Coal and the New Mine Stone being 32 feet.

The measurements given in the preceding table are the extremes which each set of beds presents at different places; several of them thinning out and ending altogether in some directions. These variations in thickness, however, take place in such a way as generally to balance each other, the mean thickness, for instance, of the whole set from the bottom of the Thick coal to the top of the Blue Flats ironstone is about 320 feet, or 106 yards, over a large space north-west of Dudley, although great changes take place in the thickness of particular sets of beds within that space.

There is apparent, however, a general thickening of the measures as we proceed northwards from Dudley to Bilston and Bloxwich, the distance between the Thick coal and the Blue Flats being only 80 yards at the Foxyards near Dudley, and 90 yards at Bradley, while it gradually increases to 120 and 130 yards about Bentley and Bloxwich, that being the thickness between the Blue Flats and the Bentley Hay coal, which is the representative of the bottom beds of the Thick coal. This thickening, however, is still more remarkable with regard to the Thick coal measures themselves, as the beds of coal which in the central district rest directly on each other are separated by spaces of 60 or 80 feet about Wyrley, the 30 feet of Thick coal in the central district being expanded to about 330 feet of shale, sandstone, and coal in the northern one.

The Blue Flats ironstone itself is scarcely worked south of Bilston, and it is not till we approach Bentley near Walsall that the Silver threads and Diamonds begin to show themselves. North of Bloxwich, on the other hand, although the other beds appear to increase still further in thickness, especially the shales and sandstones, splitting up and separating the coals that were near or close together further south, yet the ironstones, so far as is yet known, appear to diminish and die away altogether, none but a few comparatively poor or lean bands having yet been discovered, either about Wyrley or near the Brown Hills.

Such being the constitution of the beds comprising the coal field, it may be useful to add a few words as to their "position and lie" in the ground.

Commencing at the northern apex of the coal field at Brereton near Rugeley, the Coal Measures appear suddenly at the surface from under the New Red Sandstone, being bounded apparently by two faults that separate wider and wider as they proceed towards the south. These two principal boundary faults are more or less traceable along the whole flanks of the coal field. The beds lying between them seem at first, about Brereton Hayes and Beaudesert Old Park, to dip gently to the east, but after that all over Cannock Chase, and as far south as Bentley, the dip is towards the west, or a little north of west, generally at an inclination of less than 5°. The lower beds rise to the surface accordingly as we approach the eastern boundary fault, the Deep (or Bottom) coal cropping out a little south-east of the Moat near Pelsall, and being traceable at the surface, thence to the neighbourhood of West Bromwich. A little east of a large part of that space, the Silurian rocks which lie below the coal measures crop out, being visible at the surface for nearly five miles, from the north of Daw End to the south of Bustleholm Mill. The measures are much broken by faults, having, generally, a nearly east and west direction, producing up-throws and down-throws to the north or south, and shifting the out-crop of any particular bed to the east and west accordingly. One large up-throw to the south, amounting in some places to a vertical displacement of 360 feet, extends right across the coal field, lifting up the lower measures so as to cause the New Mine coal to crop out all across the district from Bentley to Wolverhampton. South of this great Bentley fault, the beds dip very gently to the south all the way to Tipton, being bent up on both sides of the coal field towards the Dudley and Sedgley anticlinal on the west as well as towards the Walsall district on the east. Between Bilston and Tipton the dip is very slight, but several east and west faults, having a downthrow to the south, contribute to bury the beds deeper in that direction, till we reach the Dudley Port Trough faults, after which the dislocations form upthrows to the south, and bring the beds

nearer to the surface as the ground rises to the Rowley Hills. These hills are capped by basalt, and it is remarkable that, in the angle of the coal field to the south-east of Rowley, all the valuable beds of coal and ironstone seem to be greatly deteriorated, if not destroyed, for some distance, partly by the intrusion of trap rock, but chiefly by what may be called a "congenital malformation," or defect in their deposition; worthless materials taking the place of those which are more valuable. To the south and west of Dudley and Rowley the beds deepen again, both from their own inclination and the effect of the Russell's Hall fault, which is a downthrow to the south-west. This south-west corner of the coal field is partially divided into two basins (which we may call the Pensnett and Cradley basins) by the effect of the Netherton anticlinal. Both these basins are traversed by several faults, and the Netherton anticlinal seems to end suddenly with a high dip to the south, so that the very uppermost beds of the coal-measure series stretch right across the whole district from Kingswinford to Halesowen and the Leasowes. South of this line the whole coal field seems to dip gently and steadily southwards beneath the Permian rocks of the Clent Hills and Frankly Beeches, and the coal measures are no more seen at or near the surface, except in some little shreds and patches on the flanks of the altered Silurian rocks of the Lickey Hills.

3. *Details of the Ironstone Measures.*

It remains now only to give some details on the different beds or sets of beds which contain workable ironstone.

I. "*Brooch Binds*" *ironstone measures.*—The Brooch binds are beds of clay or shale just underneath the Brooch coal. They only contain ironstone to the south-west of Dudley. They average there about 7 feet in thickness, containing nodules of ironstone which are sometimes, but not always, worth getting. This is about Corbyn's Hall and Bromley Hall, and also near Corngreaves. About Brierly Hill and at Wordesley Bank they contain good ironstone, and the "binds" thicken out to 20 feet.

II. "*Pins and Pennyearth" ironstone measures.*—These take their names from the form of the ironstone nodules which they contain, the Pins being small round or cylindrical nodules, and the Pennyearth small flattish nodules like penny pieces. They are found on both sides of Dudley, being spoken of as from 7 to 20 feet thick about Tividale, Tipton, and Oldbury, but are now principally gotten to the south-west about Corbyn's Hall and Brierly Hill, and also near Congreaves. At Wordesley Bank the measures containing the Pins were said to be 4 feet, and those containing the Pennyearth 27 feet.

Mention is occasionally made of ironstone about this horizon even as far north as Bradley near Bilston.

III. "*Ten-foot stone" and "Backstone" ironstone.*—It is, I believe, only about Brierly Hill that these ironstones have ever been found. The Backstone is so called from its lying immediately above, or on the *back* of, the Thick Coal; the Ten-foot stone, from its occurring just ten feet above the Thick Coal.

IV. *The "Grains" and "Whitery" ironstones.*—These are merely occasional ironstones which sometimes occur in beds called "Blacktery" and "Whitery" consisting of dark coloured and light coloured clunch. The beds themselves are sometimes absent altogether, and they never exceed 6 or 8 feet in thickness even when they contain most ironstones.

V. *The "Gubbin ironstone,"* sometimes called the "*Little or Thick Coal Gubbin,*" and sometimes near Dudley known as the "*Black stone,*" is one of the most widely diffused and most exclusively worked of all the beds of ironstone in the coal field. The following is a detailed section of it as it occurred at Upper Gornal, and was noted by Mr. Kenyon Blackwell:—

	Ft.	In.
Ironstone (called Gubbin) -	0	6
Dark Clunch - - -	2	0
Ironstone (called Cannock) -	0	6
Dark Clunch - - -	2	0
Ironstone (called Rubble) -	0	3
Black Batt - - -	0	6
	5	9

The Gubbin measures consist principally of dark clunch, and the stone is usually dark coloured, occurring in either one, two, or three layers of nodules. The total thickness of the whole varies from 2 to 9 feet in different places.

In the district of Bentley near Walsall, and, I believe there only, there occur two small ironstone bands of good quality between Nos. V. and VI. They lie a little below the Heathen Coal, the following being the section supplied by Mr. George of Bentley :—

	Ft.	In.
Heathen Coal - - -	1	8
Clunch and Ironstone - -	9	10
Lambstone (Ironstone) - -	0	3
Clunch - - -	2	6
Black Batt - - -	1	0
Brownstone (Ironstone) - -	0	6
Clunch, Ironstone, and Black Batt -	3	3

This Brownstone is said to resemble the Blackband of Scotland. Neither of these ironstones are known anywhere to the southward of the great Bentley fault.

VI. *New Mine Ironstone or White Stone.*—This is perhaps still more widely diffused and more largely worked than the Gubbin, being known from Bentley on the north to Halesowen on the south, a distance of 10 miles. It is a light coloured ironstone occurring in large nodules lying in a bed of clay which is called "clunch," "clod," or "binds" according to its minor varieties. The layers of nodules vary from 2 to 4, and the whole measure from 2 feet to 10 feet in thickness, the most usual being 4 or 5 feet. The following details will give a good idea of its variations. The places are arranged in order from north to south.

1. *Northern Part of Bentley Estate.*

	In.	Ft.	In.
Ironstone - -	3	0	3
Clunch - - - -		0	7
Ironstone - -	4	0	4
Clunch - - -		3	3
Ironstone - -	4	0	4
	11	4	9

2. *Chillington Colliery near Wolverhampton.*

	In.	Ft. In.
Top Ironstone	3	0 3
Clunch	-	3 3
Bottom Ironstone	18	1 6
	21	5 0

3. *Highfields near Bilston.*

	In.	Ft. In.
Ironstone	3	0 3
Clunch	-	1 10
Ironstone	3	0 3
Clunch	-	1 10
Ironstone	6	0 6
	12	4 8

4. *Foxyards near Dudley.*

	In.	Ft. In.
Ironstone	5	0 5
Clunch	-	1 6
Ironstone	1	0 1
Clunch	-	1 3
Ironstone	3	0 3
	9	3 6

5. *Gornal Clay Works.*

	In.	Ft. In.
White Clunch	-	1 6
Ironstone	3	0 3
White Clunch	-	2 0
Dark Clunch	-	1 0
Ironstone	6	0 6
	9	5 3

6. *Corbyn's Hall.*

	In.	Ft. In.
Top Ironstone	9	0 9
Clunch	-	5 6
Bottom Stone	12	1 0
	21	7 3

7. *Dudley Woodside.*

	In.	Ft. In.
Ironstone - -	$2\frac{1}{2}$ - -	0 $2\frac{1}{2}$
Clunch, &c. - - - -		4 0
Ironstone - -	$3\frac{1}{2}$ - -	0 $3\frac{1}{2}$
	6	4 6

8. *Kingswinford Colliery.*

	In.	Ft. In.
Top Ironstone - -	6 - -	0 6
Measures - - -		6 10
Bottom Ironstone -	10 - -	0 10
	16	8 2

In the Pensnett and Cradley basins and in the district around Dudley, as far east as Oldbury and as far north as Ettingshall Lane, this ironstone is almost invariably called the White stone. It is, over that space, almost the lowest stone ever gotten, and the one on which the principal dependence has been placed of late years. North of Ettingshall, about Wolverhampton, Bilston, and Walsall, it is always called the New Mine Stone, and it is there one of the uppermost ironstones, richer and more important beds beginning to set in below it.

VII. "*Pennystone, Bluestone, or Cakes.*"—The beds in which this ironstone lies are dark clay, sometimes black, and generally spoken of as clunch or clod. The ironstone occurs in flat roundish nodules of a dark colour, so as to be readily distinguishable from the white ironstone above it.

In the district to the south-west of Dudley, ironstone has rarely, if ever, been found on this horizon or below it.

It is well known towards Oldbury under the name of Cakes or Bluestone, and between Wolverhampton and Walsall as Pennystone.

Near Oldbury fossil shells are abundant in the upper part of the Cakes and bottom of the Whitestone, both the shells known formerly as Unio and now called Cardinia and

Anthrocosia, and others such as Producta scabricula, Avicula quadrata, Pecten? unnamed, Lingula mytiloides? Orbicula nitida, Conularia quadrisulcata, also an Echinus probably Archæocidaris, and fish teeth and bones. It is remarkable that the shells called Cardinia are never, or very rarely, mingled in the same mass of stone with any of the other shells, except in rare instances with a solitary Lingula.

VIII. "*FireclayBalls" ironstone.*—The measures containing this ironstone are most variable and capricious, and of course the ironstone is equally uncertain in its occurrence. In the Stow Heath and Priestfield collieries between Bilston and Wolverhampton, where there are many pits within the space of half a mile, these measures vary from a seam of clay 2 or 3 feet in thickness, to a mass of sandstone 39 feet thick with a little fireclay above and below it. Wherever the clay predominates and beds of 5 or 6 feet of argillaceous matter occur, there come in occasional balls of ironstone, making a layer sometimes 3 feet in thickness. These are called the Fireclay balls as occurring above the Fireclay coal.

IX. "*Getting Rock" ironstone.*—Below the Fireclay coal there is generally from 2 to 10 feet of fireclay, after which a sandstone is frequently met with, sometimes containing balls of ironstone sufficient to be worth getting. It is then called "the Getting Rock." It seems to be confined to the neighbourhood of Stow Heath, Ettingshall, Deepfields, and Bradley, and does not always occur even there.

X. "*Poor Robin" ironstone.* — This ironstone is more widely diffused and persistent than that of the Getting Rock. The measure is sometimes three or four feet thick.

XI. "*Rough Hills Whitestone.*"—This ironstone appears to be absolutely confined to the district between Bilston and Wolverhampton. It was first worked at the Rough Hills south of Wolverhampton. At Parkfields the measures were 19 feet 2 inches thick, containing 11 bands of ironstone

from 1 inch to 6 inches thick, making a total of 32 inches of ironstone; but elsewhere it is never more than 3 or 4 feet thick, with not more than 6 or 8 inches of ironstone.

XII. "*Gubbin and Balls*" *ironstone, sometimes called the Bottom or Great Gubbin to distinguish it from* No. V.—This, as a measure containing good workable ironstone, occurs only between Wolverhampton and Walsall, and around Bilston.

At Chillington Colliery it had the following form:—

	In.	Ft. In.
Balls of ironstone - -	8	- - 0 8
Clod - - - -		- 2 6
Balls of ironstone - -	6	- - 0 6
Dark clod - - -		- 1 6
Gubbin ironstone -	6	- - 0 6
Clod - - - -		- 1 0
Gubbin ironstone - -	3	- 0 3
	23	6 11

The balls are generally distinctly septarian, the septa or internal fissures being lined with crystals of iron pyrites and sometimes with those of galena and blende.

XIII. "*Blue Flats*" *ironstone.*—This ironstone is so called from the flat pavement-like form in which it occurs, together with its weathering of a dull purplish blue after exposure to the atmosphere. It is confined absolutely, as a workable measure, to the district between Wolverhampton and Walsall, being scarcely known south of Bilston on the one hand, nor north of Bloxwich on the other. The following are some detailed accounts of it:—

1. *Park Hall, just South of Wolverhampton.*

	In.	Ft. In.
Topstone - - -	6	- - 0 6
Binds, &c. - - -		- 2 0
Secondstone - -	3	- - 0 3
Parting - - -		- 1 3
Thirdstone - -	4	- - 0 4
Ground with Chitterstone -		- 4 2
Bottom stone - -	3	- - 0 3
	16	8 9

2. *Bentley Estate.*

	In.	Ft. In.
Ironstone	4	0 4
Binds		3 0
Ironstone	1	0 1
Binds		1 6
Ironstone	2	0 2
	7	5 1

3. *Ryecroft near Walsall.*

	In.	Ft. In.
Ironstone cake	3	0 3
Blue clod		1 0
Ironstone	3	0 3
	6	1 6

Farther north, at Dudley Brothers colliery and near Pelsall, although the measures have been sunk through and recognized, neither the Blue Flats nor the two following ironstones were found, nor anything but a little "lean" ironstone supposed to represent them.

XIV. "*Silver Threads*" *ironstone.*—This seems to be confined to the district round Walsall. It occurs from 5 to 14 feet below the Blue Flats. The measure consists of clay (binds or clod) from 4 to 7 feet in thickness, containing two or three bands of ironstone each from 1 to 4 inches in thickness. It was named from little threads of shining spar which traversed the ironstone.

XV. "*Diamonds*" *ironstone.*—This was also named from the crystals of spar it contained, which in the miners' eyes resembled diamonds, just as quartz crystals are sometimes spoken of as Bristol or Irish diamonds. It is separated from No. XIV. by from 6 to 15 feet of binds, &c. The measure is from 2 to 4 feet thick (binds or clod), containing two layers of ironstone from 2 to 4 inches each. It is occasionally mentioned as recognisable near Wolverhampton, but as a workable bed it is confined, like the Silver-threads, to the district just west of Walsall.

J. BEETE JUKES.

Analyses of Iron Ores—*continued from page 97.*

continued from page 97.

XXII.—Brooch Ironstone, Corngreaves. (By J. Spiller.)

(No. I. of General Section. *See* pp. 103. and 107.)

Description.—Clay iron ore; colour, greyish brown; fracture, uneven. The ore is uniform in character, with the exception of small tubular cavities filled with white clay, in which zinc-blende occurs.

Analysis by Method No. III.

	Grs.
Water, hygroscopic and total amount:—	
51·885 grs. of ore lost of water at 100° C.	0·28
37·02 grs. of ore gave of water at a red heat	0·69
By the action of hydrochloric acid—	
15·16 grs. of ore gave of—	
Insoluble residue	2·88
Peroxide of iron (containing 0·07 gr. of silica)	7·45
Alumina	0·16
Manganoso-manganic oxide ($Mn_3 O_4$)	0·16
Sulphate of lime	0·56
Pyrophosphate of magnesia	0·49
The insoluble residue gave of—	
Silica	1·88
Alumina	0·775
Peroxide of iron	0·09
Sulphate of lime	0·055
Ammonio-phosphate of magnesia	trace.
24·21 grs. of ore gave of—	
Organic matter	0·215
Sulphate of potash	0·19
Sulphuric acid and sulphur as pyrites:—	
46·915 grs. of ore gave of—	
Sulphate of baryta (from sulphates)	0·02
Sulphate of baryta (from bisulphide of iron)	0·56
Phosphoric acid:—	
112·79 grs. of ore gave of pyrophosphate of magnesia	1·47
Carbonic acid:—	
I. 33·27 grs. of ore gave of carbonic acid	9·36
II. 27·51 " "	7·765

Iron by standard solution of permanganate of potash:—

Standard: 1 gr. of iron = 81·76 cub. cent. of solution.

Weight of ore.	Cub. cent. of solution.	Per cent. iron.
9·91	29·7	34·20

Results Tabulated.

	I.	II.
Protoxide of iron - -	43·81	43·97
Protoxide of manganese -	0·98	
Alumina - - -	1·05	
Lime - - -	1·52	
Magnesia - - -	1·15	
Carbonic acid - -	28·22	28·13
Phosphoric acid - -	0·83	
Silica, soluble in hydrochloric acid - -	0·46	
Sulphuric acid - - -	trace.	
Bisulphide of iron - -	0·30	
Water, hygroscopic -	0·54	
„ combined - -	1·32	
Organic matter - -	0·88	
Ignited insoluble residue -	18·80	
	99·86	

Ignited Insoluble Residue.

Silica - - -	12·40
Alumina - - -	5·11
Peroxide of iron - -	0·39
Lime - - - -	0·15
Magnesia - - -	trace.
Potash - - -	0·42
	18·47

Iron, total amount - - 34·35

Besides zinc, occurring in the form of blende, a minute trace of a white metal, too small to identify, was found in 460 grains of the ore.

XXIII.—Pins, Dudley. (By A. Dick.)

(No. 181 of the Illustrated Catalogue.—No. II. of General Section. *See* pp. 104. and 108.)

Description.—Clay iron ore; colour, greyish black; structure, compact and homogeneous, with spots of white crystalline matter very sparingly diffused through it.

Analysis chiefly by Method No. III.

Water, hygroscopic and combined :—	grs.
34·16 grs. of ore lost of water at 100° C. - - - -	0·12
And gave of water at a red heat - - - - -	0·56
By the action of hydrochloric acid :—	
17·94 grs. of ore gave of—	
Insoluble residue - - - - - -	2·86
Peroxide of iron - - - - - -	9·01
Manganoso-manganic oxide - - - -	0·11
Alumina - - - - - -	0·11
Sulphate of lime - - - - -	4·13
Pyrophosphate of magnesia - - - -	0·60
Silica - - - - - - -	0·12
5·67 grs. of insoluble residue gave of—	
Silica - - - - - -	3·65
Alumina - - - - - -	1·82
Peroxide of iron - - - - -	0·24
Oxalate of lime - - - - -	trace.
Pyrophosphate of magnesia - - - -	0·04
34·06 grs. of ore gave of—	
Organic matter - - - - -	0·54
Chloride of potassium - - - - -	0·20
Phosphoric and sulphuric acids, and bisulphide of iron.	
35·42 grs. of ore gave of pyrophosphate of magnesia -	0·26
28·80 grs. of ore gave of—	
Sulphate of baryta (from sulphates) - - -	trace.
Sulphate of baryta (from bisulphide of iron) - -	0·24
30·89 grs. of ore gave of carbonic acid - -	9·30

Results tabulated.—Ore dried at 100° C.

Protoxide of iron - - -	45·35
Protoxide of manganese - -	0·56
Alumina - - - -	0·61
Lime - - - - -	2·60
Magnesia - - - -	1·22
Carbonic acid - - - -	30·21
Phosphoric acid - - -	0·46
Sulphuric acid - - - -	trace.
Silica - - - -	0·67
Bisulphide of iron - - -	0·20
Water - - - -	1·64
Organic matter - - - -	1·59
Ignited insoluble residue - -	15·87
	100·98

Ignited Insoluble Residue.

Silica - - - - -	9·96
Alumina - - - -	5·09
Peroxide of iron - - - -	0·54
Lime - - - - -	trace.
Magnesia - - - - -	0·04
Potash - - -	0·36
	15·99

Iron, total amount - - -	35·74

By treatment of the hydrochloric acid solution of 600 grs. of ore with sulphuretted hydrogen, and reduction before the blowpipe, a trace of whitish metal was obtained. It was too small in quantity to be identified.

XXIV.—Penny Earth, Dudley. (By A. Dick.)

(No. 182 of the Illustrated Catalogue.—No. II. of General Section. *See* pp. 104. and 108.)

Description.—Clay iron ore; colour, greyish brown; structure, compact and homogeneous.

Analysis by Method No. II.

Water, hygroscopic and combined :—	grs.
39·56 grs. of ore lost of water at 100° C. - - - -	0·32
And gave of water at a red heat - - -	0·51
By the action of hydrochloric acid —	
15·21 grs. of ore gave of insoluble residue - -	3·96
The hydrochloric acid solution and the solution of the residue gave of—	
Peroxide of iron - - - - -	6·36
Manganoso-manganic oxide - - - -	0·10
Alumina - - - - -	1·25
Sulphate of lime - - - - -	1·00
Pyrophosphate of magnesia - - -	1·08
Silica - - - - - - -	2·74
41·31 grs. of ore gave of—	
Organic matter - - - - - -	0·63
Chloride of potassium - - - -	0·28
Phosphoric and sulphuric acids, and bisulphide of iron :—	
59·10 grs. of ore gave of pyrophosphate of magnesia -	0·61
39·57 grs. of ore gave of—	
Sulphate of baryta (from sulphates) - - -	trace.
Sulphate of baryta (from bisulphide of iron) - -	0·35
50·09 grs. of ore gave of carbonic acid - - -	12·88

Results tabulated.—Ore dried at 100° *C.*

Protoxide of iron - - -	37·69
Protoxide of manganese - -	0·61
Alumina - - - -	8·24
Lime - - - -	2·72
Magnesia - - - -	2·60
Potash - - - -	0·43
Carbonic acid - - - -	25·92
Phosphoric acid - - -	0·66
Sulphuric acid - - -	trace.
Silica - - - -	18·11
Bisulphide of iron - - -	0·22
Water - - - -	1·29
Organic matter - - -	1·56
	100·05

Iron, total amount - - -	29·42
Clay, after ignition* - - -	25·51

No metal precipitable by sulphuretted hydrogen from the hydrochloric acid solution of 600 grs. of ore was detected.

XXV.—Grains, Dudley. (By A. Dick.)

(No. 187 of the Illustrated Catalogue.—No. IV. of General Section. *See* pp. 104. and 108.)

Description.—Clay iron ore; colour, greyish black; structure, compact and homogeneous. The ore is covered in some places with a thin layer of yellowish white matter.

Analysis by Method No. II.

	grs.
Water, hygroscopic :—	
54·39 grs. of ore lost of water at 100° C. - -	0·12
Water, total amount :—	
58·51 grs. of ore gave of water at a red heat - -	0·76
By the action of hydrochloric acid :—	
26·55 grs. of ore gave of insoluble residue - -	0·91
The hydrochloric acid solution and the solution of the residue gave of—	
Peroxide of iron - - - - -	16·00
Manganoso-manganic oxide - - - -	0·59
Alumina - - - - -	0·215
Sulphate of lime - - - -	1·42
Pyrophosphate of magnesia - - - -	0·46
Silica - - - - - -	0·56
40·43 grs. of ore gave of—	
Organic matter - - - - -	0·55
Chloride of potassium - - - -	trace.
Phosphoric and sulphuric acids and bisulphide of iron :—	
53·06 grs. of ore gave of pyrophosphate of magnesia -	0·58
37·12 grs. of ore gave of—	
Sulphate of baryta (from sulphates) - -	trace.
Sulphate of baryta (from bisulphide of iron) - -	0·53
53·84 grs. of ore gave of carbonic acid - - -	18·94

* Clay means the residue insoluble in hydrochloric acid; it has the composition of fire-clay. In the analyses in which the term *clay* is used as above, no separate analysis of the insoluble residue was made.

Results tabulated. Ore dried at 100° C.

Protoxide of iron - - -	54·12
Protoxide of manganese - -	2·05
Alumina - - - -	0·78
Lime - - - -	2·21
Magnesia - - - -	0·62
Potash - - - -	trace.
Carbonic acid - - -	35·25
Phosphoric acid - - -	0·69
Sulphuric acid - - -	trace.
Silica - - - -	2·11
Bisulphide of iron - - -	0·40
Water - - - -	1·07
Organic matter - - -	1·36
	100·66

Iron, total amount - - -	42·26
Clay, after ignition - - -	3·43

No metal precipitable by sulphuretted hydrogen from the hydrochloric acid solution of 900 grs. of ore was detected.

XXVI.—Gubbin Ironstone, Gubbin, Dudley.

(By A. Dick.)

(No. 188 of the Illustrated Catalogue.—No. V. of General Section. *See* pp. 104, and 108.)

Description.—Clay iron ore; colour, greyish black; structure, compact and homogeneous. It contains thin veins of white and reddish brown matter, in which zinc-blende, galena, and copper pyrites occur.

Analysis by Method No. I.

Water hygroscopic and combined :—	grs.
45·70 grs. of ore lost of water at 100° C.	0·14
42·75 grs. of ore gave of water at a red heat	0·72
By the action of hydrochloric acid :—	
16·18 grs. of ore gave of—	
Insoluble residue	2·47
Peroxide of iron	8·295
Manganoso-manganic oxide	0·25
Alumina	0·07
Carbonate of lime	0·22
Pyrophosphate of magnesia	0·42
Silica	0·02
The insoluble residue gave of—	
Silica	1·645
Alumina	0·705
Peroxide of iron	0·03
Lime and magnesia	traces.
45·70 grs. of ore gave of organic matter	0·52
Phosphoric and sulphuric acids and bisulphide of iron :—	
76·78 grs. of ore gave of pyrophosphate of magnesia	0·90
37·36 grs. of ore gave of—	
Sulphate of baryta (from sulphates)	trace.
Sulphate of baryta (from bisulphide of iron)	0·11
14·69 grs. of ore gave of carbonic acid	4·46

Results tabulated.—Ore dried at 100° C.

Protoxide of iron	46·30
Protoxide of manganese	1·44
Alumina	0·44
Lime	0·76
Magnesia	0·94
Carbonic acid	30·44
Phosphoric acid	0·74
Sulphuric acid	trace.
Silica soluble in acid	0·12
Bisulphide of iron	0·07
Water	1·38
Organic matter	1·14
Ignited insoluble residue	15·26
	99·03

Ignited Insoluble Residue.

Silica - - - -	10·17
Alumina - - - -	4·36
Peroxide of iron - - -	0·13
Lime and magnesia - - -	traces.
Potash - - -	undetermined.
	14·66
Iron, total amount - - -	36·14

No metal precipitable by sulphuretted hydrogen from the hydrochloric acid solution of 500 grs. of ore was detected.

XXVII.—Gubbin Ironstone, Cannock, Dudley. (By A. Dick.)

(No. 189 of the Illustrated Catalogue.—No. V. of General Section. *See* pp. 104. and 108.)

Description.—Clay iron ore; colour, greyish brown; structure, compact and homogeneous. It contains thin veins of greyish white matter, and blende.

Analysis by Method No. I.

	grs.
Water, hygroscopic and combined :—	
66·14 grs. of ore lost of water at 100° C. -	0·24
and gave of water at a red heat - - -	0·715
By the action of hydrochloric acid.	
19·27 grs. of ore gave of :—	
Insoluble residue - - - -	3·065
Peroxide of iron - - - -	9·74
Manganoso-manganic oxide - - -	0·20
Alumina - - - - -	0·08
Carbonate of lime - - - -	0·41
Pyrophosphate of magnesia - - -	0·87
Silica - - - - -	0·08
The insoluble residue gave of—	
Silica - - - - -	1·98
Alumina - - - - -	1·05
Peroxide of iron - - - -	0·09
Carbonate of lime - - - -	0·07
Pyrophosphate of magnesia - - -	0·11
46·84 grs. of ore gave of organic matter - -	0·43

Phosphoric and sulphuric acids and bisulphide of iron :—

73·45 grs. of ore gave of pyrophosphate of magnesia	0·24
53·59 grs. of ore gave of—	
Sulphate of baryta (from sulphates)	trace.
Sulphate of baryta (from bisulphide of iron)	0·19
16·66 grs. of ore gave of carbonic acid	5·15

Results tabulated.—Ore dried at 100° C.

Protoxide of iron	45·86
Protoxide of manganese	0·96
Alumina	0·42
Lime	1·17
Magnesia	1·65
Carbonic acid	31·02
Phosphoric acid	0·21
Sulphuric acid	trace.
Silica soluble in acid	0·42
Bisulphide of iron	0·10
Water	1·08
Organic matter	0·90
Ignited insoluble residue	15·90
	99·69

Ignited Insoluble Residue.

Silica	10·26
Alumina	5·44
Peroxide of iron	0·40
Lime	0·20
Magnesia	0·20
Potash	undetermined.
	16·50

Iron, total amount	35·99

No metal precipitable by sulphuretted hydrogen from the hydrochloric acid solution of 500 grs. of ore was detected.

XXVIII.—Gubbin Ironstone, Rubble, Dudley.

(By A. Dick.)

(No. 190 of the Illustrated Catalogue.—No. V. of General Section. *See* pp. 104. and 108.)

Description.—Clay iron ore; colour, greyish black; structure, compact and homogeneous.

Analysis by Method No. I.

Water hygroscopic and combined :—	grs.
53·44 grs. of ore lost of water at 100° C. - -	0·19
47·89 grs. of ore lost of water at a red heat - -	0·97
By the action of hydrochloric acid :—	
17·26 grs. of ore gave of	
Insoluble residue - - - -	4·15
Peroxide of iron - - - -	7·68
Manganoso-manganic oxide - - -	0·10
Alumina - - - - -	0·09
Carbonate of lime - - - -	0·26
Pyrophosphate of magnesia - - -	0·63
Silica - - - - -	0·15
The insoluble residue gave of—	
Silica - - - - -	3·14
Alumina - - - - -	0·77
Peroxide of iron - - - -	0·10
Carbonate of lime - - - -	0·21
Pyrophosphate of magnesia - - -	0·07
53·25 grs. of ore gave of organic matter - -	1·04
Phosphoric and sulphuric acid and bisulphide of iron :—	
76·82 grs. of ore gave of pyrophosphate of magnesia -	0·37
50·35 grs. of ore gave of sulphate of baryta (from sulphates)	trace.
30·42 grs. of ore gave of—	
Sulphate of baryta (from bisulphide of iron) - -	0·13
29·16 grs. of ore gave of carbonic acid - - -	7·71

Results tabulated.—Ore dried at 100° C.

Protoxide of iron	40·28
Protoxide of manganese	0·54
Alumina	0·52
Lime	0·84
Magnesia	1·33
Carbonic acid	26·53
Phosphoric acid	0·30
Sulphuric acid	trace.
Silica soluble in acid	0·87
Bisulphide of iron	0·09
Water	1·69
Organic matter	1·99
Ignited insoluble residue	24·06
	99·04

Ignited Insoluble Residue.

Silica	18·20
Alumina	4·46
Peroxide of iron	0·52
Lime	0·68
Magnesia	0·14
Potash	undetermined.
	24·00

Iron, total amount	31·70

No metal precipitable by sulphuretted hydrogen from the hydrochloric acid solution of 500 grs. of ore was detected.

XXIX.—Whitestone Bind, Dudley. (By J. Spiller.)

(No. VI. of General Section. *See* pp. 104. and 109.)

Description.—Clay iron ore; colour, pale brown grey; fracture, sub-conchoidal, inclining to rough. The ore has a vein of carbonate of lime in which small crystals of galena occur.

Analysis by Method No. III.

Water, hygroscopic:—	grs.
I. 18·98 grs. of ore lost of water at 100° C.	0·115
II. 25·79 „ „	0·145
Water, total amount:—	
I. 30·01 grs. of ore yielded of water at a red heat	0·67
II. 23·75 „ „	0·57
By the action of hydrochloric acid:—	
15·145 grs. of ore gave of—	
Insoluble residue	5·74
Peroxide of iron (containing 0·025 grs. of silica)	5·215
Alumina	0·02
Manganoso-manganic oxide (Mn_3O_4)	0·12
Carbonate of lime	0·48
(Above converted into sulphate of lime	0·64)
Pyrophosphate of magnesia	1·225
The insoluble residue from 7·705 grs. of ore gave of—	
Silica	2·03
Alumina	0·73
Peroxide of iron	0·095
Oxalate of lime	trace.
Pyrophosphate of magnesia	0·045
34·49 grs. of ore gave of—	
Organic matter	0·035
Sulphate of potash	0·47
Phosphoric and sulphuric acids, and bisulphide of iron:—	
91·80 grs. of ore gave of—	
Pyrophosphate of magnesia	0·375
28·90 grs. of ore gave of—	
Sulphate of baryta (from sulphates)	trace.
Sulphate of baryta (from bisulphide of iron)	0·135
Carbonic acid:—	
I. 36·15 grs. of ore gave of carbonic acid	8·00
II. 22·15 „ „	4·86

Additional Determinations by Method of Analysis No. I.

10·50 grs. of ore gave of—	
Insoluble residue	3·92
Carbonate of lime	0·33
Pyrophosphate of magnesia	0·895
14·67 grs. of ore gave of—	
Insoluble residue	5·54
Carbonate of lime	0·48

Results tabulated.

	I.	II.
Protoxide of iron - -	30·96	
Protoxide of manganese -	0·73	
Alumina - - -	0·13	
Lime - - - -	1·84	1·76
Magnesia - - -	2·90	3·03
Carbonic acid - -	22·13	21·94
Phosphoric acid - -	0·26	
Silica, soluble in hydrochloric acid - - -	0·15	
Sulphuric acid - -	trace.	
Bisulphide of iron - -	0·12	
Water, hygroscopic -	0·56	0·60
" in combination -	1·83	1·65
Organic matter - -	0·10	
Ignited insoluble residue -	37·90	37·76
	99·61	

Ignited Insoluble Residue.

Silica - - -	26·35
Alumina - - -	9·45
Peroxide of iron - -	1·15
Lime - - -	trace.
Magnesia - - -	0·21
Potash - - -	0·74
	37·90

Iron, total amount - - 24·88

A trace of lead was found in 300 grains of the ore.

XXX.—Bottom White Stone, Dudley.

(By J. Spiller.)

(No. VI. of General Section. *See* pp. 104 and 109.)

Description. — Clay iron ore, irregularly seamed with numerous small veins of carbonate of lime, which appear in some cases to be in the form of shells; colour, greyish brown; fracture, irregular, being determined by the position of the seams of carbonate of lime. A small quantity of white clay also occurs in the ore.

Analysis by Method No. III.

	grs.
Water, hygroscopic and combined.	
26·785 grs. of ore lost of water at 100° C. - -	0·085
and yielded of water at a red heat - - -	0·33
Water, total amount.	
24·87 grs. of ore gave of water at a red heat - -	0·37
By the action of hydrochloric acid:	
15·11 grs. of ore gave of —	
Insoluble residue - - - -	1·42
Peroxide of iron (containing 0·06 grs. of silica) -	8·225
Alumina - - - - -	0·085
Manganoso-manganic oxide (Mn_3O_4) - -	0·21
Carbonate of lime - - - -	1·20
Pyrophosphate of magnesia - - -	0·34
The insoluble residue from 13·83 grs. of ore gave of—	
Silica - - - - -	0·815
Alumina - - - - -	0·425
Peroxide of iron - - - -	0·02
Oxalate of lime - - } Ammonio-phosphate of magnesia } - -	traces.
23·44 grs. of ore gave of—	
Sulphate of baryta (from sulphates) - -	0·04
Organic matter - - - -	0·065
Chloride of potassium - - -	0·04
Phosphoric acid and sulphur as pyrites.	
115·77 grs. of ore gave of —	
Pyrophosphate of magnesia - - -	0·56
21·15 grs. of ore gave of—	
Sulphate of baryta - - - -	0·135
Carbonic acid.	
I. 33·94 grs. of ore gave of carbonic acid - -	10·86
II. 33·39 „ „ - - -	10·74

Results tabulated.

Protoxide of iron - - -	48·63
Protoxide of manganese - -	1·29
Alumina - - - -	0·57
Lime - - - -	4·45
Magnesia - - -	0·80
Carbonic acid - - - -	32·16
Phosphoric acid - - -	0·31
Silica, soluble in hydrochloric acid -	0·33
Sulphuric acid - - -	0·06
Bisulphide of iron - - -	0·16
Water, hygroscopic - - -	0·32
„ combined - - -	1·23
Organic matter - - - -	0·28
Ignited insoluble residue - -	9·40
	99·99

Ignited Insoluble Residue.

Silica - - - -	5·88
Alumina - - - - -	3·07
Peroxide of iron - - -	·04
Lime, Magnesia - - - -	traces.
Potash - - - - -	0·11
	9·10

Iron, total amount - - -	37·45

None of the metals, precipitable by sulphuretted hydrogen from the hydrochloric acid solution, were found in 300 grains of the ore.

XXXI.—White Stone, Rough Hay Colliery, Darlaston.

(By C. Tookey.)

(No. VI. of General Section. *See* pp. 104. and 109.)

Description.—Clay iron ore; colour, pale brown grey; structure, compact and very homogeneous; microscopic crystals of copper pyrites occur very sparingly diffused through the ore.

Analysis by Method No. III.

	grs.
Water, hygroscopic :—	
18·985 grs. of ore lost of water at 110° C.	0·08
Water, combined :—	
51·675 grs. of ore dried at 110° C. gave at a red heat	0·51
By the action of hydrochloric acid :—	
27·078 grs. of ore gave of—	
Insoluble residue (ignited)	6·945
Manganoso-manganic oxide	0·225
Alumina	0·185
Sulphate of lime	1·615
Pyrophosphate of magnesia	3·09
Silica	0·025
6·49 grs. of insoluble residue (ignited) gave of—	
Silica	4·59
Alumina	1·46
Peroxide of iron	0·20
Sulphate of lime	0·13
Pyrophosphate of magnesia	0·23
41·775 grs. of ore gave of—	
Organic matter	0·195
56·92 grs. of ore gave of—	
Chloride of potassium in the soluble portion	0·135
" " insoluble portion	0·56
Phosphoric acid :—	
39·55 grs. of ore gave of—	
Pyrophosphate of magnesia	0·22
34·80 grs. of ore gave of—	
Sulphate of baryta (from bisulphide of iron)	0·21
I. 8·74 grs. of ore gave of carbonic acid	2·35
II. 8·822 " "	2·40
III. 9·91 " "	2·635

Iron, total amount (soluble) by standard solution of bichromate of potash :—

Standard. 1 gr. of iron = 14·87 cub. cent. of solution.

Weight of ore.	Cub. cent. of solution.	Per cent. of iron.
I. 6·95	29·35	28·39
II. 9·63	40·40	28·26
Iron, existing in the state of protoxide :—		
I. 7·40	29·00	26·34
II. 9·235	36·30	26·42

Results tabulated.

Protoxide of iron	33·92
Peroxide of iron	2·77
Protoxide of manganese	0·77
Alumina	0·67
Lime	2·45
Magnesia	4·11
Silica (soluble in hydrochloric acid)	0·09
Potash	0·14
Carbonic acid	26·89
Phosphoric acid	0·35
Bisulphide of iron	0·15
Water, hygroscopic	0·42
„ in combination	0·98
Organic matter	0·47
Ignited insoluble residue	25·55
	99·73

Ignited Insoluble Residue.

Silica	18·14
Alumina	5·77
Peroxide of iron	0·40
Lime	0·20
Magnesia	0·32
Potash	0·60
	25·43

Iron, total amount	28·87

The presence of copper was distinctly proved in 500 grs. of ore; a second experiment on 600 grs. of ore gave the same result.

XXXII.—Cakes, or Blue Stone, Dudley.

(By A. Dick.)

(Nos. 198 and 198*a* of the Illustrated Catalogue.—No. VII. of General Section. *See* pp. 104 and 111.)

Description.—Clay iron ores; colour, greyish brown; structure, compact and homogeneous; containing veins of carbonate of lime.

Analysis by Method No. I.

Water, hygroscopic and combined:—	grs.
30·61 grs. of ore lost of water at 100° C.	0·07
41·39 grs. of ore gave of water at a red heat	0·29
By the action of hydrochloric acid:—	
18·91 grs. of ore gave of—	
Insoluble residue	1·06
Peroxide of iron	10·61
Manganoso-manganic oxide	0·67
Alumina	0·045
Carbonate of lime	0·40
Pyrophosphate of magnesia	1·03
Silica	0·05
1·15 grs. of insoluble residue gave of—	
Silica	0·69
Alumina	0·34
Peroxide of iron	0·10
Carbonate of lime	0·03
Pyrophosphate of magnesia	0·03
Phosphoric and sulphuric acids, and bisulphide of iron:—	
119·60 grs. of ore gave of—	
Pyrophosphate of magnesia	0·44
26·92 grs. of ore gave of—	
Sulphate of baryta (from sulphates)	trace.
26·75 grs. of ore gave of—	
Sulphate of baryta (from bisulphide of iron)	0·15
17·35 grs. of ore gave of carbonic acid	6·14

Results tabulated.—Ore dried at 100° C.

Protoxide of iron - - -	50·60
Protoxide of manganese - -	3·30
Alumina - - -	0·24
Lime - - - -	1·19
Magnesia - - - -	1·98
Carbonic acid - - -	35·47
Phosphoric acid - - -	0·23
Sulphuric acid - - -	trace.
Silica, soluble in acid - -	0·27
Bisulphide of iron - - -	0·13
Water - - - -	0·47
Organic matter - -	undetermined.
Ignited insoluble residue -	5·52
	99·40

Ignited Insoluble Residue.

Silica - - - -	3·31
Alumina - - - -	1·63
Peroxide of iron - - -	0·38
Lime - - - -	0·08
Magnesia - - - -	0·06
Potash - - -	undetermined.
	5·46

Iron, total amount - -	39·71

No metal precipitable by sulphuretted hydrogen from the hydrochloric acid solution of 200 grs. of ore was detected.

XXXIII.—Cakes, or Blue Stone, Dudley.

(By A. Dick.)

(No. 199 of the Illustrated Catalogue.—No. VII. of General Section. *See* pp. 104. and 111.)

Description.—Clay iron ore; colour, greyish brown; structure, compact and homogeneous. It is coated in some places with a yellowish-white substance.

Analysis by Method No. I.

	grs.
Water, hygroscopic and combined:—	
45·33 grs. of ore lost of water at 100° C.	0·15
48·45 grs. of ore gave of water at a red heat	0·47
By the action of hydrochloric acid:—	
14·68 grs. of ore gave of—	
Insoluble residue	1·79
Peroxide of iron	7·125
Manganoso-manganic oxide	0·26
Alumina	0·035
Carbonate of lime	0·40
Pyrophosphate of magnesia	1·83
Silica	0·05
The insoluble residue gave of—	grs.
Silica	1·12
Alumina	0·52
Peroxide of iron	0·17
Carbonate of lime	0·06
Pyrophosphate of magnesia	0·04
Phosphoric and sulphuric acids, and bisulphide of iron:—	
87·69 grs. of ore gave of—	
Pyrophosphate of magnesia	0·21
35·16 grs. of ore gave of—	
Sulphate of baryta (from sulphates)	0·06
37·84 grs. of ore gave of—	
Sulphate of baryta (from sulphates and bisulphide of iron)	0·77
36·71 grs. of ore gave of—	
Carbonic acid	12·44

Results tabulated.—Ore dried at 100° C.

Protoxide of iron	43·55
Protoxide of manganese	1·65
Alumina	0·23
Lime	1·53
Magnesia	4·65
Carbonic acid	34·00
Phosphoric acid	0·15
Sulphuric acid	0·06
Silica, soluble in acid	0·34
Bisulphide of iron	0·47
Water	0·64
Organic matter	undetermined.
Ignited insoluble residue	11·95
	99·22

Ignited Insoluble Residue.

Silica	7·47
Alumina	3·47
Peroxide of iron	0·84
Lime	0·19
Magnesia	0·09
Potash	undetermined.
	12·06

Iron, total amount	34·88

No metal precipitable by sulphuretted-hydrogen from the hydrochloric acid solution of 600 grs. of ore was detected.

XXXIV.—Fire Clay Balls, Dudley. (By A. Dick.)

(Nos. 200 and 201*b* of the Illustrated Catalogue.—No. VIII. of General Section. *See* pp. 104 and 112.)

Description.—Coarse-grained, crystalline carbonates of protoxide of iron, varying in colour from light to dark brown, containing veins of white and reddish-brown matter. 201*b* is lighter in colour, and the veins of white matter are more numerous than in 200.

Analysis by Method No. III.

Water, hygrosoopic and combined :—	grs.
34·75 grs. of ore lost of water at 100° C. - -	0·13
and gave of water at a red heat - - -	0·515
By the action of hydrochloric acid :—	
17·525 grs. of ore gave of—	
Insoluble residue - - - -	3·23
Manganoso-manganic oxide - - -	0·19
Alumina - - - - -	0·095
Sulphate of lime - - - -	0·44
Pyrophosphate of magnesia - - -	0·64
The insoluble residue gave of—	
Silica - - - - -	2·06
Alumina - - - - -	1·06
Peroxide of iron - - - -	0·12
Carbonate of lime - - - -	0·03
47·55 grs. of ore gave of—	
Organic matter - - - -	0·10
Chloride of potassium - - - -	0·22
Phosphoric and sulphuric acids, and bisulphide of iron :—	
43·68 grs. of ore gave of pyrophosphate of magnesia -	0·13
36·82 grs. of ore gave of—	
Sulphate of baryta (from sulphates) - -	0·13
Sulphate of baryta (from bisulphide of iron) -	0·24
26·37 grs. of ore gave of carbonic acid - -	7·89

Iron by standard solution of bichromate of potash —
Standard: 1 gr. of iron = 8·45 cub. cent. of solution.

	Weight of ore.	Cub. cent. of solution.	Per cent. iron.
I.	12·49	38·0	35·98
II.	8·47	25·7	35·90

Results tabulated.—Ore dried at 100° C.

Protoxide of iron - - -	46·39
Protoxide of manganese - -	1·01
Alumina - - - -	0·54
Lime - - - -	1·03
Magnesia - - - -	1·33
Carbonic acid - - -	30·00
Phosphoric acid - - -	0·11
Sulphuric acid - - -	0·10
Bisulphide of iron - - -	0·17
Water - - - -	1·50
Organic matter - - -	0·21
Ignited insoluble residue - -	18·39
	100·78

Ignited Insoluble Residue.

Silica - - - -	11·71
Alumina - - - -	6·04
Peroxide of iron - - -	0·57
Lime - - - -	0·09
Potash - - - -	0·28
	18·69

Iron, total amount - -	36·56

No metal precipitable from the hydrochloric acid solution of 1140 grs. of ore was detected.

XXXV.—Fire Clay Balls, Dudley. (By A. Dick.)

(No. 201*a* of the Illustrated Catalogue.—No. VIII. of General Section. *See* pp. 104 and 112.)

Description.—Fine-grained, crystalline carbonate of protoxide of iron; colour, greyish-brown. It contains veins of calc-spar, and white pulverulent silicate of alumina, in which occur small white crystalline globular concretions, consisting of carbonate of lime and magnesia.

Analysis by Method No. III.

	grs.
Water, hygroscopic :—	
32·47 grs. of ore lost of water at 100° C.	0·115
Water, total amount :—	
28·09 grs. of ore gave of water at a red heat	0·45
By the action of hydrochloric acid :—	
20·655 grs. of ore gave of —	grs.
Insoluble residue	3·305
Manganoso-manganic oxide	0·26
Alumina	0·09
Sulphate of lime	0·51
Pyrophosphate of magnesia	0·72
The insoluble residue gave of —	
Silica	2·18
Alumina	1·04
Peroxide of iron	0·09
Sulphate of lime	0·05
36·79 grs. of ore gave of —	
Organic matter	0·15
Chloride of potassium	0·22
Phosphoric and sulphuric acids, and bisulphide of iron :—	
32·31 grs. of ore gave of pyrophosphate of magnesia	0·04
35·86 grs. of ore gave of —	
Sulphate of baryta (from sulphates)	0·09
Sulphate of baryta (from bisulphide of iron)	0·24
31·95 grs. of ore gave of carbonic acid	9·86

Iron by standard solution of bichromate of potash :—
Standard : 1 gr. of iron = 8·45 cub. cent. of solution.

	Weight of ore.	Cub. cent. of solution.	Per cent. iron.
I.	13·95	43·4	36·82
II.	11·185	35·2	37·24

Results tabulated.—Ore dried at 100° C.

Protoxide of iron - - -	47·87
Protoxide of manganese - -	1·12
Alumina - - - -	0·43
Lime - - - -	1·00
Magnesia - - - -	1·27
Carbonic acid - - -	30·96
Phosphoric acid - - -	0·07
Sulphuric acid - - -	0·08
Bisulphide of iron - - -	0·17
Water - - - -	1·18
Organic matter - - -	0·41
Ignited insoluble residue - -	15·95
	100·51

Ignited Insoluble Residue.

Silica - - - -	10·52
Alumina - - - -	5·02
Peroxide of iron - - -	0·33
Lime - - - -	0·13
Potash - - - -	0·38
	16·38

Iron, total amount - - -	37·47

No metal precipitable from the hydrochloric acid solution of 750 grs. of ore was found.

XXXVI.—Poor Robin's, Bunker's Hill. (By A. Dick.)

(Nos. 203 and 203*a* of the Illustrated Catalogue.—No. X. of General Section. *See* pp. 104 and 112.)

Description.—Clay iron ore; colour, various shades of greyish black; structure, compact. It is seamed with numerous veins of white and yellowish white substance.

Analyis by Method No. III.

	grs.
Water, hygroscopic and combined :—	
33·87 grs. of ore lost of water at 100° C.	0·07
and gave of water at a red heat	0·44
By the action of hydrochloric acid :—	
19·065 grs. of ore gave of—	
Insoluble residue	1·92
Manganoso-manganic oxide	0·20
Alumina	0·09
Sulphate of lime	0·86
Pyrophosphate of magnesia	0·97
The insoluble residue gave of—	
Silica	1·20
Alumina	0·45
Peroxide of iron	0·12
Sulphate of lime	0·05
50·00 grs. of ore gave of organic matter	0·62
34·74 grs. of ore gave of chloride of potassium	0·20
Phosphoric and sulphuric acids, and bisulphide of iron :—	
36·95 grs. of ore gave of pyrophosphate of magnesia	0·20
49·82 grs. of ore gave of—	grs.
Sulphate of baryta (from sulphates)	0·14
Sulphate of baryta (from bisulphide of iron)	0·36

Iron, by standard solution of bichromate of potash :—
Standard: 1 gr. of iron = 8·45 cub. cent. of solution.

Weight of dry ore.	Cub. cent. of solution.	Per cent. iron.
I. 13·56	44·4	38·74
II. 7·39	24·0	38·43

Results tabulated.—Ore dried at 100° C.

Protoxide of iron - - -	49·61
Protoxide of manganese - -	0·98
Alumina - - - -	0·50
Lime - - - -	1·86
Magnesia - - - -	1·86
Carbonic acid - - -	33·05
Phosphoric acid - - -	0·34
Sulphuric acid - - -	0·10
Bisulphide of iron - - -	0·17
Water - - - -	1·30
Organic matter - - -	1·24
Ignited insoluble residue - -	10·02
	101·03

Ignited Insoluble Residue.

Silica - - - -	6·26
Alumina - - - -	2·35
Peroxide of iron - - -	0·53
Lime - - - -	0·03
Potash - - - -	0·39
	9·56

Iron, total amount - - -	39·02

A trace of copper was detected in the hydrochloric acid solution of 1030 grs. of ore.

XXXVII. Rough Hill Whitestone (good sample), Darlaston. (By A. Dick.)

(No. 205 of the Illustrated Catalogue.—No. XI. of General Section. *See* pp. 104 and 112.)

Description.—Clay iron ore; colour, brown to greyish black; structure, compact, homogeneous.

Analysis by Method No. II.

	grs.
Water, hygroscopic:—	
38·56 grs. of ore lost of water at 100° C.	0·12
So much tarry matter was evolved when the ore was heated to redness, that an accurate determination of the water combined with the clay could not be made.	
By the action of hydrochloric acid:—	
15·335 grs. of ore gave of—	
Insoluble residue	2·635
Peroxide of iron	7·56
Manganoso-manganic oxide	0·40
Alumina	0·06
Sulphate of lime	0·36
Pyrophosphate of magnesia	0·43
Silica	0·15
15·53 grs. of ore gave of organic matter	0·415
Phosphoric and sulphuric acids, and bisulphide of iron:—	
76·95 grs. of ore gave of pyrophosphate of magnesia	0·81
38·29 grs. of ore gave of—	
Sulphate of baryta (from sulphates)	0·08
Sulphate of baryta (from bisulphide of iron)	0·62
22·96 grs. of ore gave of carbonic acid	6·645

Results tabulated.—Ore dried at 100° C.

Protoxide of iron	44·20
Protoxide of manganese	2·43
Alumina	0·37
Lime	0·96
Magnesia	1·04
Carbonic acid	29·03
Phosphoric acid	0·66

Sulphuric acid - - -	0·05
Silica - - - - -	0·98
Bisulphide of iron - - -	0·26
Water - - -	undetermined.
Organic matter - - -	2·68
Ignited insoluble residue - -	17·04
	99·70
Iron, total amount - - -	34·53

XXXVIII. Rough Hill Whitestone (bad sample), Darlaston. (By A. Dick.)

(No. 205 of the Illustrated Catalogue.—No. XI. of General Section. *See* pp. 104. and 112.)

Description.—Clay iron ore, containing shale.

Analysis by Method No. II.

Water, hygroscopic and combined:—	grs.
44·58 grs. of ore lost of water at 100° C. - -	0·33
Owing to the large amount of tarry matter produced by heating the ore to low redness, the amount of water combined with the clay could not be determined.	
By the action of hydrochloric acid:—	
20·36 grs. of ore gave of insoluble residue - -	6·21
The hydrochloric acid solution, and the solution of the residue, gave of—	
Peroxide of iron - - - - - -	7·51
Manganoso-manganic oxide - - -	0·44
Alumina - - - - - - - -	1·56
Pyrophosphate of magnesia (from phosphoric acid in ore)	0·16
Carbonate of lime - - - - - -	0·45
Pyrophosphate of magnesia (from magnesia in ore) -	0·58
Silica - - - - - -	4·54
54·05 grs. of ore gave of organic matter about - -	5·29
Chloride of potassium - - - -	0·77
65·52 grs. of ore gave of—	
Sulphate of baryta (from sulphates) - - -	0·08
Sulphate of baryta (from bisulphide of iron) - -	1·04
18·67 grs. of ore gave of carbonic acid - - -	3·88

Results tabulated.—Ore dried at 100° C.

Protoxide of iron - - -	33·19
Protoxide of maganese - -	2·02
Alumina - - - - -	7·71
Lime - - - -	1·24
Magnesia - - - -	1·04
Potash - - - -	0·90
Carbonic acid - - - -	20·94
Phosphoric acid - - -	0·50
Sulphuric acid - - -	0·04
Silica - - - -	22·48
Bisulphide of iron - - -	0·41
Water - - -	undetermined.
Organic matter, about - - -	9·87
	100·34
Iron, total amount - - -	26·01

A trace of copper was detected in 500 grs. of ore.

XXXIX. Rough Hill Whitestone, Rough Hay Colliery, Darlaston. (By C. Tookey.)

(No. XI. of General Section. *See* pp. 104. and 112.)

Description.—Clay iron ore; colour, brown; structure, compact and homogeneous. Veins of hydrated silicate of alumina, peroxide of iron, and copper pyrites occur in it.

Analysis by Method No. III.

Water, hygroscopic (not estimated).

	grs.
Water, total amount:—	
I. 63·38 grs. of ore gave at a read heat - - - - -	0·69
II. 69·19 „ „ - - - - -	0·735
By the action of hydrochloric acid:—	
19·155 grs. of ore gave:—	
Insoluble residue (ignited) - - - -	2·655
Manganoso-manganic oxide - - -	0·135
Alumina - - - - - -	0·135
Sulphate of lime - - - - -	0·525
Pyrophosphate of magnesia - - -	0·625
Silica - - - - - -	0·105

7·27 grs. of insoluble residue (ignited) gave of—

Silica	4·05
Alumina	2·47
Peroxide of iron	0·29
Sulphate of lime	0·14
Pyrophosphate of magnesia	0·22
Protoxide of manganese	trace.

42·80 grs. of ore gave of—

Organic matter	0·21
Chloride of potassium in the soluble portion	0·155
Chloride of potassium in the insoluble portion	0·555

Phosphoric acid:—

33·505 grs. of ore gave of—

Pyrophosphate of magnesia	0·20

43·05 grs. of ore gave of—

Sulphate of baryta (from bisulphide of iron)	0·23
I. 8·50 grs. of ore gave of carbonic acid	2·56
II. 8·365 grs. " "	2·515

Iron, total amount (soluble in hydrochloric acid) by standard solution of bichromate of potash:—

Standard: 1 gr. of iron = 14·82 cub. cent. of solution.

	Weight of ore.	Cub. cent. of solution.	Per cent. of iron.
I.	7·715	43·660	38·14
II.	6·735	38·15	38·22
Iron existing in the state of protoxide:—			
I.	6·915	37·00	36·11
II.	7·07	38·05	36·32

Results tabulated.

Protoxide of iron	46·56
Peroxide of iron	2·80
Protoxide of manganese	0·65
Alumina	0·70
Lime	1·13
Magnesia	1·18
Silica	0·54
Potash	0·23
Carbonic acid	30·08
Phosphoric acid	0·38
Bisulphide of iron	0·13
Water	1·07
Organic matter	0·50
Ignited insoluble residue	13·77
	99·72

Ignited Insoluble Residue.

Silica - - - -	7·72
Alumina - - - -	4·70
Peroxide of iron - - -	0·39
Lime - - - - -	0·11
Magnesia - - - -	0·15
Potash . - - - -	0·82
Protoxide of manganese - -	trace.
	13·89
Iron, total amount - - -	38·56

The presence of copper was distinctly proved in 800 grs. of ore.

XL.—Gubbin and Balls, Bunker's Hill Colliery.

(By A. Dick.)

(No. 206 of the Illustrated Catalogue.—No. XII. of General Section. *See* pp. 104 and 113.)

Description.—Clay iron ore; colour, greyish brown; structure, compact, seamed by white pulverulent silicate of alumina, and grey crystalline carbonate of lime.

Analysis by Method No. I.

	grs.
Water, hygroscopic and combined :—	
37·64 grs. of ore lost of water at 100° C. - -	0·23
and gave of water at a red heat - - -	0·37
By the action of hydrochloric acid :—	
14·935 grs. of ore gave of—	
Insoluble residue - - - - -	3·405
Manganoso-manganic oxide - - -	0·15
Alumina - - - - -	0·165
Sulphate of lime - - - -	0·76
Pyrophosphate of magnesia - - - -	1·12
The insoluble residue gave of—	
Silica - - - - -	2·42
Alumina - - - - -	0·77
Peroxide of iron - - - -	0·13
Oxalate of lime - - - - -	trace.
Pyrophosphate of magnesia - - -	0·12
24·94 grs. of ore gave of—	
Organic matter - - - - -	0·13
Chloride of potassium - - -	0·24

Phosphoric and sulphuric acids, and bisulphide of iron :—

44·96 grs. of ore gave of pyrophosphate of magnesia	0·22
38·65 grs. of ore gave of—	
Sulphate of baryta (from sulphates)	trace.
Sulphate of baryta (from bisulphide of iron)	0·10
22·16 grs. of ore gave of carbonic acid	6·17

Iron by standard solution of bichromate of potash:—

Standard; 1 gr. of iron = 8·44 cub. cent. of solution.

Weight of ore.	Cub. cent. of solution.	Per cent. iron.
I. 8·40	21·6	30·45
II. 9·25	23·8	30·48

Results tabulated.—Ore dried at 100° C.

Protoxide of iron	39·51
Protoxide of manganese	0·94
Alumina	1·12
Lime	2·11
Magnesia	2·76
Carbonic acid	28·08
Phosphoric acid	0·31
Sulphuric acid	trace.
Bisulphide of iron	0·05
Water	0·98
Organic matter	0·52
Ignited insoluble residue	22·96
	99·34

Ignited Insoluble Residue.

Silica	16·31
Alumina	5·13
Peroxide of iron	0·85
Lime	trace.
Magnesia	0·30
Potash	0.65
	23·24

Iron, total amount	31·34

A minute trace of lead was detected in 740 grs. of the ore.

XLI.—Gubbin and Balls, Bunker's Hill Colliery.

(By A. Dick.)

(No. 207 of the Illustrated Catalogue.—No. XII. of General Section. *See* pp. 104. and 113.)

Description.—Clay iron ore; colour, greyish brown; structure, compact. It contains veins of greyish white pulverulent silicate of alumina, and traces of galena.

Analysis by Method No. III.

Water, hygroscopic and combined :—	grs.
48·63 grs. of ore lost of water at 100° C.	0·19
and gave of water at a red heat	0·225
By the action of hydrochloric acid :—	
11·61 grs. of ore gave of—	grs.
Insoluble residue	1·30
Manganoso-manganic oxide	0·115
Alumina	0·15
Sulphate of lime	0·15
Pyrophosphate of magnesia	0·27
The insoluble residue gave of—	
Silica	0·785
Alumina	0·43
Peroxide of iron	0·06
Oxalate of lime	trace.
Pyrophosphate of magnesia	0·10
44·78 grs. of ore gave of—	
Organic matter	0·23
Chloride of potassium	0·23
Phosphoric and sulphuric acids, and bisulphide of iron :—	
40·76 grs. of ore gave of pyrophosphate of magnesia	0·14
43·59 grs. of ore gave of—	
Sulphate of baryta (from sulphates)	trace.
Sulphate of baryta (from bisulphide of iron)	0·23
28·99 grs. of ore gave of carbonic acid	9·33

Iron by standard solution of bichromate of potash :—

Standard: 1 gr. of iron=8·84 cub. cent. of solution.

Weight of ore.	Cub. cent. of solution.	Per cent. iron.
I. 10·47	35·7	40·39
II. 9·48	32·2	40·24

Results tabulated.—Ore dried at 100° C.

Protoxide of iron - - -	52·04
Protoxide of manganese - -	0·92
Alumina - - - -	1·30
Lime - - - -	0·53
Magnesia - - - -	0·85
Carbonic acid - - -	32·31
Phosphoric acid - - -	0·21
Sulphuric acid - - -	trace.
Bisulphide of iron - - -	0·13
Water - - - -	0·46
Organic matter - - -	0·51
Ignited insoluble residue - -	11·14
	100·40

Ignited Insoluble Residue.

Silica - - - -	6·63
Alumina - - - -	3·68
Peroxide of iron - - -	0·43
Lime - - - -	trace.
Magnesia - - - -	0·33
Potash - - - -	0·32
	11·39

Iron, total amount - - -	40·84

No metal precipitable by sulphuretted hydrogen from the hydrochloric acid solution of 720 grs. of ore was detected.

XLII.—Gubbin and Balls, Balls, Rough Hay Colliery, Darlaston. (By C. Tookey.)

(No. XII. of General Section. *See* pp. 104 and 113.)

Description. — Clay iron ore; colour, greyish black; structure, compact. It is seamed with veins of greyish white silicate of alumina, in which minute crystals of zinc-blende, iron pyrites, and copper pyrites occur.

Analysis by Method No. III.

	grs.
Water hygroscopic :—	
27·00 grs. of ore lost at 110° C.	0·07
Water total amount :—	
I. 59·67 grs. of ore gave at a red heat	0·61
II. 49·495 grs. of ore ,,	0·51
By the action of hydrochloric acid :—	
18·83 grs. of ore gave of—	
Insoluble residue (ignited)	2·30
Manganoso-manganic oxide	0·16
Alumina	0·04
Sulphate of lime	0·32
Pyrophosphate of magnesia	0·30
Silica	0·05
7·07 grs. of insoluble residue (ignited) gave of—	
Silica	4·44
Alumina	2·055
Peroxide of iron	0·25
Sulphate of lime	0·13
Pyrophosphate of magnesia	0·15
Protoxide of manganese	trace.
52·855 grs. of ore gave of—	
Organic matter	0·315
Chloride of potassium in the portion soluble in acid	0·09
Chloride of potassium in the portion insoluble in acid	0·27
Phosphoric acid.	
38·745 grs. of ore gave of—	
Pyrophosphate of magnesia	0·11
54·59 grs. of ore gave of—	
Sulphate of baryta (from bisulphide of iron)	0·20
I. 7·30 grs. of ore gave of carbonic acid	2·255
II. 9·035 grs. of ore gave of carbonic acid	2·775

Iron, total amount (soluble in hydrochloric acid) by standard solution of bichromate of potash.

Standard: 1 gr. of iron=14·82 cub. cent. of solution.

	Weight of ore.	Cub. cent. of solution.	Per cent. of iron.
I.	6·565	39·30	40·40
II.	8·315	50·05	40·63
Iron existing in the state of protoxide.			
I.	6·68	37·70	38·08
II.	4·945	23·00	38·21

Results tabulated.

Protoxide of iron - - -	49·04
Peroxide of iron - - -	3·39
Protoxide of manganese - -	0·79
Alumina - - - -	0·21
Lime - - - -	0·70
Magnesia - - - -	0·57
Silica, soluble in hydrochloric acid -	0·27
Potash - - - -	0·10
Carbonic acid - - -	30·80
Phosphoric acid - - -	0·18
Bisulphide of iron - - -	0·11
Water, hygroscopic - - -	0·26
" in combination - -	0·77
Organic matter - - -	0·60
Ignited insoluble residue - -	12·15
	99·94

Ignited Insoluble Residue.

Silica - - - -	7·67
Alumina - - - -	3·55
Peroxide of iron - - -	0·36
Lime - - - -	0·09
Magnesia - - - -	0·09
Potash - - - -	0·32
Protoxide of manganese - -	trace.
	12·08

Iron, total amount - - -	40·81

The presence of copper was distinctly proved in 800 grs. of ore.

XLIII.—Gubbin and Balls, Gubbin, Rough Hay Colliery, Darlaston. (By C. Tookey.)

(No. XII. of General Section. *See* pp. 104. and 113.)

Description.—Clay iron ore; colour, greyish black; structure, compact. It contains white pulverulent silicate of alumina, a large quantity of zinc-blende and minute crystals of iron pyrites.

Analysis by Method No. III.

	grs.
Water, hygroscopic,	
25·62 grs. of ore lost of water at 110° C. - -	0·095
Water, combined.	
83·71 grs. of ore dried at 110° C. gave at a red heat -	0·25
By the action of hydrochloric acid:	
25·62 grs. of ore gave of—	
Insoluble residue (ignited) - - -	2·435
Manganoso-manganic oxide - - -	0·235
Alumina - - - - - -	0·065
Silica - - - - - -	0·06
Sulphate of lime - - - -	0·425
Pyrophosphate of magnesia - - -	0·32
The insoluble residue (ignited) gave of—	
Silica - - - - - -	1·535
Alumina - - - - - -	0·695
Peroxide of iron - - - - -	0·075
Sulphate of lime - - - - -	0·105
Pyrophosphate of magnesia - - -	0·05
70·485 grs. of ore gave of—	
Organic matter - - - - -	0·38
Chloride of potassium from soluble portion - -	0·10
Chloride of potassium from insoluble portion -	0·17
Phosphoric acid.	
33·307 grs. of ore gave of—	
Pyrophosphate of magnesia - - -	0·12
Sulphur.	
36·743 grs. of ore gave of—	
Sulphate of baryta, from sulphide of zinc and bisulphide of iron - - - - - -	1·295
I. 12·80 grs. of ore gave of carbonic acid - - -	4·095
II. 8·92 " " - - -	2·865
Zinc.	
47·15 grs. of ore gave of oxide of zinc - - -	0·50

Iron, total amount (soluble) by standard solution of bichromate of potash.

Standard: 1 gr. of iron = 14·87 cub. cent. of solution.

Weight of ore.	Cub. cent. of solution.	Per cent. of iron.
I. 6·91	42·00	40·86
II. 9·14	55·55	40·86
Iron existing in the state of protoxide.		
I. 8·31	47·35	38·31
II. 10·69	61·00	38·36

Results tabulated.

Protoxide of iron	49·30
Peroxide of iron	3·61
Protoxide of manganese	0·86
Alumina	0·34
Lime	0·69
Magnesia	0·45
Silica	0·23
Potash	0·09
Carbonic acid	32·05
Phosphoric acid	0·23
Bisulphide of iron	0·13
Sulphide of zinc	1·27
Hygroscopic water	0·37
Combined "	0·29
Organic matter	0·54
Ignited insoluble residue	9·42
	99·87

Ignited Insoluble Residue.

Silica	5·99
Alumina	2·71
Peroxide of iron	0·21
Lime	0·17
Magnesia	0·07
Potash	0·21
	9·36
Iron, total amount	41·06

No metal precipitable by sulphuretted hydrogen from the hydrochloric acid solution of 400 grains of ore was detected.

The zinc was determined by digesting the ore with nitro-hydrochloric acid; the solution was nearly neutralized with carbonate of soda, and the peroxide of iron separated by boiling with acetate of soda; the filtrate was saturated with sulphuretted hydrogen and the sulphide of zinc dissolved

in hydrochloric acid; the oxide was precipitated by carbonate of soda from the boiling solution, ignited, and weighed.

XLIV.—Blue Flats Ironstone, Rough Hay Colliery, Darlaston. (By C. Tookey.)

(No. XIII. of General Section. *See* pp. 104. and 113.)

Description.—Clay iron ore; colour, various shades of pale brown. The ore is irregularly seamed with veins of calc-spar, with greyish white and reddish brown silicate of alumina, containing minute crystals of iron pyrites.

Analysis by Method No. III.

Water, hygroscopic.	
13·90 grs. of ore lost of water at 110° C. - -	0·04
Water, combined.	
54·19 grs. of ore dried at 110° C. gave at a red heat -	0·40
By the action of hydrochloric acid:	
14·09 grs. of ore gave of—	
Insoluble residue (ignited) - - - -	2·19
Manganoso-manganic oxide - - -	0·17
Alumina - - - - - -	0·084
Silica - - - - - -	0·05
Sulphate of lime - - - - -	1·33
Pyrophosphate of magnesia - - -	0·58
The insoluble residue gave of—	
Silica - - - - - -	1·525
Alumina - - - - - -	0·515
Peroxide of iron - - - - -	0·045
Protoxide of manganese - - - -	trace.
Lime and magnesia - - - -	traces.
43·22 grs. of ore gave of—	
Organic matter - - - - -	0·24
Chloride of potassium - - - -	0·575
51·74 grs. of ore gave of—	
Pyrophosphate of magnesia - - -	0·20
Sulphate of baryta, from bisulphide of iron - -	0·13
I. 13·325 grs. of ore gave of carbonic acid - -	4·12
II. 7·00 " " - - -	2·145

Iron, total amount (soluble) by standard solution of bichromate of potash.

Standard: 1 gr. of iron = 6·86 cub. cent. of solution.

Weight of ore.	Cub. cent. of solution.	Per cent. of iron.
I. 19·685	46·10	34·12
II. 19·220	45·20	34·26
Iron, existing in the state of protoxide.		
17·45	39·45	32·93

Results tabulated.

Protoxide of iron	42·34
Peroxide of iron	1·47
Protoxide of manganese	1·12
Alumina	0·59
Lime	3·89
Magnesia	1·48
Silica	0·35
Carbonic acid	30·91
Phosphoric acid	0·25
Sulphuric acid	trace.
Bisulphide of iron	0·06
Hygroscopic water	0·28
Combined „	0·73
Organic matter	0·56
Ignited insoluble residue	15·50
	99·53

Ignited Insoluble Residue.

Silica	10·82
Alumina	3·65
Peroxide of iron	0·11
Protoxide of manganese	trace.
Lime and magnesia	traces.
Potash	0·84
	15·42

Iron, total amount	34·41

No metal precipitable by sulphuretted hydrogen in the hydrochloric acid solution was found in 400 grs. of the ore.

XLV. Silver Threads, Rough Hay Colliery, Darlaston.

(By C. Tookey.)

(No. XIV. of General Section. *See* pp. 104. and 114.)

Description.—Clay iron ore; colour, greyish brown. The ore is irregularly seamed with numerous veins of calc-spar, coated with drab coloured ferruginous matter.

Analysis by Method No. III.

Water, hygroscopic:—	
19·165 grs. of ore lost of water at 110° C	0·065
Water combined:—	
48·80 grs. of ore dried at 110° C gave at a red heat	0·285
By the action of hydrochloric acid:—	
19·165 grs. of ore gave of—	
Insoluble residue (ignited)	2·035
Manganoso-manganic oxide	0·155
Alumina	0·036
Sulphate of lime	3·41
Pyrophosphate of magnesia	1·15
Silica	0·035
6·87 grs. of insoluble residue (ignited) gave of—	
Silica	4·26
Alumina	2·00
Peroxide of iron	0·24
Sulphate of lime	0·06
Pyrophosphate of magnesia	0·10
Protoxide of manganese	trace.
51·665 grs. of ore gave of—	
Organic matter	0·41
Chloride of potassium, soluble ·115, insoluble ·225	0·34
Phosphoric acid:	
44·35 grs. of ore gave of—	
Pyrophosphate of magnesia	0·15
Sulphuric acid and bisulphide of iron:—	
35·587 grs. of ore gave of sulphate of baryta	trace.
60·135 grs. of ore gave of—	
Sulphate of baryta from bisulphide of iron	0·25
I. 12·836 grs. of ore gave of carbonic acid	4·285
II. 11·825 grs. „ „	3·94

Iron, total amount (soluble) by standard solution of bichromate of potash:—

Standard: 1 gr. of iron = 14·87 cub. cent. of solution.

	Weight of ore.	Cub. cent. of solution.	Per cent. of iron.
I.	10·695	52·50	33·00
II.	9·975	49·25	33·19
Iron existing in the state of protoxide:—			
	9·69	45·30	31·42

Results tabulated.

Protoxide of iron - - -	40·39
Peroxide of iron - - - -	2·38
Protoxide of manganese - -	0·75
Alumina - - - -	0·19
Lime - - - -	7·30
Magnesia - - - -	2·16
Silica soluble in hydrochloric acid -	0·18
Potash - - - -	0·07
Carbonic acid - - - -	33·35
Phosphoric acid - - -	0·22
Bisulphide of iron - - -	0·11
Hygroscopic water - - -	0·33
Combined water - - -	0·60
Organic matter - - -	0·80
Ignited insoluble residue - -	10·52
	99·35

Ignited Insoluble Residue.

Silica - - - -	6·56
Alumina - - - -	3·08
Peroxide of Iron - - -	0·37
Lime - - - - -	0·04
Magnesia - - - -	0·06
Potash - - - -	0·26
Protoxide of manganese - -	trace.
	10·37

Iron, total amount - - -	33·44

No metal precipitable from the hydrochloric acid solution by sulphuretted hydrogen was detected in 600 grs. of ore.

XLVI. Diamonds, Rough Hay Colliery, Darlaston.

(By C. Tookey.)

(No. XV. of General Section. *See* pp. 104. and 114.)

Description.—Clay iron ore; colour, dark grey; structure, compact and homogeneous. It contains veins of calc-spar, and silicate of alumina in which galena, zinc-blende, copper pyrites, and iron pyrites occur.

Analysis by Method No. III.

Water, hygroscopic.	
15·285 grs. of ore lost at 110° C	0·06
Water, total amount.	
I. 65·80 grs. of ore gave at a red heat	0·725
II. 47·45 „ „	0·54
By the action of hydrochloric acid:	
37·735 grs. of ore gave of—	
Insoluble residue (ignited)	7·10
Manganoso-manganic oxide	0·305
Alumina	0·175
Sulphate of lime	2·36
Pyrophosphate of magnesia	2·83
Silica	0·10
The insoluble residue (ignited) gave of—	
Silica	5·06
Alumina	2·075
Peroxide of iron	0·24
Sulphate of lime	0·075
Pyrophosphate of magnesia	0·15
Protoxide of manganese	trace.
42·875 grs. of ore gave of—	
Organic matter	0·47
Chloride of potassium in the portion soluble in acid	0·13
Chloride of potassium in the portion insoluble	0·34
Phosphoric acid.	
55·595 grs. of ore gave of—	
Pyrophosphate of magnesia	0·18
42·39 grs. of ore gave of—	
Sulphate of baryta (from bisulphide of iron)	0·105
I. 8·79 grs. of ore gave of carbonic acid	2·56
II. 11·39 „ „	3·32

Iron, total amount (soluble in hydrochloric acid) by standard solution of bichromate of potash:

Standard: 1 gr. of iron = 14·82 cub. cent. of solution.

	Weight of ore.	Cub. cent. of solution.	Per cent. of iron.
I.	8·865	43·05	32·77
II.	7·155	34·90	32·91
Iron existing in the state of protoxide:			
	6·245	28·80	31·12

Results tabulated.

Protoxide of iron - - -	40·01
Peroxide of iron - -	2·46
Protoxide of manganese - -	0·75
Alumina - - - - -	0·46
Lime - - - - - -	2·58
Magnesia - - - -	2·70
Silica - - - - -	0·27
Potash - - - -	0·19
Carbonic acid - - - -	29·13
Phosphoric acid - - -	0·21
Water, hygroscopic - - -	0·39
,, in combination - - -	0·72
Bisulphide of iron - - -	0·06
Organic matter - - -	1·06
Ignited insoluble residue - -	18·77
	99·76

Ignited Insoluble Residue.

Silica - - - -	13·45
Alumina - - - -	4·22
Peroxide of iron - - -	0·59
Lime - - - -	0·08
Magnesia - - - -	0·14
Potash - - - -	0·18
Protoxide of manganese - -	trace
	18·66

Iron, total amount - - -	33·28

Traces of lead and copper were found in the hydrochloric acid solution of 800 grs. of ore.

XLVII.—Diamonds, Darlaston. (By A. Dick.)

(No. 211 *a.* of the Illustrated Catalogue.—No. XV. of General Section. *See* pp. 104. and 114.)

Description. — Clay iron ore; colour, dark greyish brown. Structure, compact and homogeneous. It is seamed with a white powder (XLVIII.) and carbonate of lime, in which minute crystals of zinc-blende occur.

Analysis by Method No. II.

	grs.
Water, hygroscopic and combined.	
56·88 grs. of ore lost of water at 100° C.	0·24
39·62 grs. of ore gave of water at a red heat	0·49
By the action of hydrochloric acid.	
19·16 grs. of ore gave of insoluble residue	2·80
The hydrochloric acid solution and the solution of the residue gave of—	
Peroxide of iron	8·96
Manganoso-manganic oxide	0·15
Alumina	1·00
Sulphate of lime	1·61
Pyrophosphate of magnesia	2·56
Silica	1·90
33·24 grs. of ore gave of—	
Organic matter	0·14
Chloride of potassium	0·46
Phosphoric and sulphuric acids and bisulphide of iron.	
54·53 grs. of ore gave of pyrophosphate of magnesia	0·19
49·93 grs. of ore gave of—	
Sulphate of baryta (from sulphates)	0·09
Sulphate of baryta (from bisulphide of iron)	1·08
50·93 grs. of ore gave of carbonic acid	16·20

Results tabulated.—Ore dried at 100° C.

Protoxide of iron	41·90
Protoxide of manganese	0·72
Alumina	5·26
Lime	3·47
Magnesia	4·89
Potash	0·87
Carbonic acid	31·94
Phosphoric acid	0·22
Sulphuric acid	0·06

Silica - - - -	9·95
Bisulphide of iron - - -	0·56
Water - - - -	0·82
Organic matter - - -	0·42
	101·08
Iron, total amount - - -	32·87
Clay, after ignition - -	14·67

No metal precipitable by sulphuretted hydrogen, from the hydrochloric acid solution of 740 grs. of ore was detected.

XLVIII.—White Substance occurring in Diamonds. (By A. Dick.)

Description.—Hydrated silicate of alumina. It occurs in veins as a white powder, accompanied with calc-spar.

Analysis by Method No. I.

5·45 grs. lost of water over sulphuric acid -	0·015
6·89 grs. lost of water by ignition - - -	1·00
and by the action of hydrochloric acid gave of—	
Insoluble residue - - - -	3·47
Alumina - - - - -	2·03
Peroxide of iron - - -	0·31
Sulphate of lime - - -	0·05
Silica soluble in acid - - -	0·02
The insoluble residue gave of—	
Silica - - - - - -	2·85
Alumina - - - - - -	0·52
Sulphate of lime - - - -	0·03
Pyrophosphate of magnesia - - -	0·03

Results tabulated.—Substance dried over sulphuric acid.

Water - - - -	14·26
Alumina - - - -	29·54
Peroxide of iron - - -	4·51
Lime - - - -	0·30
Silica soluble in acid - -	0·29
Residue insoluble in hydrochloric acid	50·51
	99·41

Ignited Insoluble Residue.

Silica - - - -	41·49
Alumina - - - -	7·45
Lime - - - -	0·18
Magnesia - - - -	0·16
	49·28

Alkalies were not sought for.

XLIX.—Brown Stone, Bloxwich. (By A. Dick.)

(No. 212 of the Illustrated Catalogue.—*See* Note to p. 104. and p. 109.)

Description.—Clay iron ore; colour, various shades of light brown; structure, compact. Veins of white pulverulent and grey crystalline substances occur in it, containing traces of galena and copper pyrites.

Two varieties of ironstone were labelled "Bloxwich" in the Great Exhibition Catalogue, numbered 212 and 213 respectively. Number 213 is a "Blackband ironstone," of which no complete analysis has been made. It is brown-black streaked with brown. It was found to contain 25·34 per cent. of metallic iron, and not less than 30·17 of organic matter. In the Illustrated Catalogue it is stated that "this is the only measure of Blackband in the South Staffordshire coalfield. It lies underneath the lowest Heathen Coal in two courses, averaging about 12 inches, and does not prove south of Bentley. There is also an ironstone called "Brownstone," which occasionally occurs near Dudley, underneath the "Gubbin-Rubble" (Illus. Cat. p. 152.), but no analysis or examination of this variety has been made.

Analysis by Method No. II.

	grs.
Water hygroscopic and combined :—	
49·14 grs. of ore lost of water at 100° C. - - -	0·24
and gave of water at a red heat - - -	0·46
By the action of hydrochloric acid :—	
19·89 grs. of ore gave of insoluble residue - - -	2·65

The hydrochloric acid solution and the solution of the residue gave of—

Peroxide of iron	10·17
Manganoso-manganic oxide	0·30
Alumina	0·70
Sulphate of lime	1·65
Pyrophosphate of magnesia	1·16
Silica	1·71
34·74 grs. of ore gave of—	
Organic matter	0·34
Chloride of potassium	0·23
Phosphoric and sulphuric acids, and bisulphide of iron :—	
27·95 grs. of ore gave of pyrophosphate of magnesia	0·27
32·54 grs. of ore gave of—	
Sulphate of baryta (from sulphates)	trace.
Sulphate of baryta (from bisulphide of iron)	0·13
30·39 grs. of ore gave of carbonic acid	9·66

Results tabulated.—Ore dried at 100° C.

Protoxide of iron	46·14
Protoxide of manganese	1·40
Alumina	3·53
Lime	3·43
Magnesia	2·13
Potash	0·41
Carbonic acid	32·04
Phosphoric acid	0·61
Sulphuric acid	trace.
Silica	8·63
Bisulphide of iron	0·10
Water	0·94
Organic matter	0·98
	100·34
Iron, total amount	35·95
Clay, after ignition	13·38

No metal precipitable by sulphuretted hydrogen from the hydrochloric acid solution of 550 grains of ore was detected.

LONDON:
Printed by GEORGE E. EYRE and WILLIAM SPOTTISWOODE,
Printers to the Queen's most Excellent Majesty.
For Her Majesty's Stationery Office.

MEMOIRS

OF THE

GEOLOGICAL SURVEY

OF

GREAT BRITAIN

AND OF THE

MUSEUM OF PRACTICAL GEOLOGY.

IRON ORES OF GREAT BRITAIN.

PART III.

IRON ORES OF SOUTH WALES.

PUBLISHED BY ORDER OF THE LORDS COMMISSIONERS OF HER MAJESTY'S TREASURY.

LONDON:
PRINTED FOR HER MAJESTY'S STATIONERY OFFICE:
PUBLISHED BY
LONGMAN, GREEN, LONGMAN, & ROBERTS.

1861.

1540.

[3077—1000—6/61.]

NOTICE.

In publishing this, the Third Part of the Memoir on the Iron Ores of Great Britain, the analyses of which were chiefly made through the liberality of Mr. Samuel Blackwell, of Dudley, I have to acknowledge the obligation we are under to Mr. E. Rogers, of Abercarn, for his valuable description of the Iron Ores of South Wales, with which he is so well acquainted. We are also indebted to him for several of the analyses contained in this part, made in his laboratory by Mr. W. Ratcliffe, and likewise to Mr. Levick, of Cwm Celyn, and to Mr. G. Clarke, of Dowlais.

I have further much pleasure in calling attention to the portion of the memoir written by Mr. J. W. Salter, relating to the Fossils of the South Welsh Coal Field, which may be said to commence a detailed inquiry that promises to be of great interest to the palæontologist, and of considerable importance to the practical miner.

RODERICK I. MURCHISON,
Director-General.

Museum of Practical Geology,
June 1861.

CONTENTS.

PART III.

IRON ORES OF SOUTH WALES.

GENERAL DESCRIPTION. (By E. ROGERS, F.G.S., &c.)

THE manufacture of iron has been carried on in South Wales from a very remote period. In almost every valley scoriæ from the old smelting hearths are yet to be found, many feet below the present surface, and covered with remains of ancient forests, which existed long before we have any authentic history of the iron trade in this district. The early process of smelting was done by the wind furnace, nearly as in India and Africa at the present day. The iron ores were all mined at the outcrop, and mostly by means of "*races*,"—that is, streams of water, which were directed upon the strata in which the ore was bedded, and, washing away the clay and shale associated with it, left the ore clean and nearly fit for use in the furnace. Remains of these "*races*" are yet found at the head of nearly every valley, and are still used in some places.

Formerly the coal-field of this district was mostly covered with forests.* It appears that the tops of many of the hills now bare of wood and covered with heath, were once heavily timbered. The iron ore was conveyed to the wood, and smelted on the mountain sides exposed to the wind, in the earlier times; and at a later period, to sites in the valleys, where water power could be made available. The ironstone on the outcrop was also, by exposure to moisture and air, converted often into oxide of iron, and was not only easier to smelt in the furnace, but in many cases gave a yield of 40 to 45 per cent. of iron.

The country became gradually deforested by the consumption of charcoal required for iron smelting, until about 1740, when wood became so scarce that the manufacture of iron was nearly extinct in South Wales; and the whole make of Great Britain in that year was only 17,350 tons.† The necessity for advance

* The remains of large trees are sometimes found preserved in the marshy ground on the table lands, and traces of the Druidic Sacred Groves: for instance, "Myuydd-ysllwyn," in Monmouthshire, literally translated, is "the hill below the Grove." At the extreme eastern end also of the basin, on the highest points of the Blorenge Mountain, large quantities of cinder from the old wind furnaces are also found.

† It appears from the statements made by Simon Sturtevant, which are confirmed by Dud Dudley, that in 1612 the annual production of iron in Great Britain exceeded 180,000 tons. This quantity gradually diminished, until in 1740 the total make was only 17,350 tons.

was now pressing, and the plans of using pit coal, practised more than one hundred years before by Simon Sturtevant, Rovenson, and Dud Dudley, were resorted to. In 1755, Mr. Anthony Bacon erected at Merthyr a furnace for smelting iron with pit coal; this plan was soon adopted elsewhere; the trade revived, and before the end of the century it was of such importance, that canals and tramroads were made from different ironworks which had been established, to communicate with the ports on the sea coast for shipment of the produce.* Such has since been the development of the resources of this district, that in 1858 the make of iron in South Wales was 886,478 tons, and the produce of coal 7,495,289 tons.†

The South Wales coal-field has been protected from denudation by a range of hills running along its north outcrop, nearly east and west, and another parallel range on the south outcrop; in both cases anticlinal lines.‡ Much of the upper measures has been washed away. These protecting barriers have also been often broken by currents from the north-west, and valleys scooped or washed out to a depth of, in some cases, more than 1,300 feet. These valleys, running nearly north and south, terminate at the different ports on the north side of the Bristol Channel, at Newport, Cardiff, Swansea, &c., and have given great natural facilities for making roads to ship the produce; and by offering points for the miner to sink his shafts much below the general level of the country, have been most important in expediting the development of the mineral resources of the district, at the same time creating a beautiful and varied landscape, equal to any in Britain.

In a former part of the Memoirs of the Geological Survey of Great Britain, Sir H. De la Beche intimates the probability of the coal-fields of Britain and Belgium being of the like age, and once joined.§ He states, "From the movement of the older "rocks many a mass of Coal-measures may be buried beneath "the oolites and cretaceous rocks on the east; the remains of "a great sheet of these accumulations, connecting the districts "we have noticed with those of central England and of Belgium, "rolled about and partially denuded prior to the deposit of the "New Red Sandstone." Sir R. Murchison holds views corroborative of this, and carries the opinion expressed nearer to actual

* Previous to this all the materials were conveyed on mules' backs; the iron was entirely sent inland, and no mineral produce shipped at the eastern ports.

† Hunt's Mineral Statistics, 1858.

‡ "A minute acquaintance with the physical relations of the country shows that "the rolls of the strata form great systems of anticlinals, synclinals, domes, and "oblong dome-shaped curvatures; the smaller contortions forming but minute por-"tions of these, having in fact, as has been remarked by Captain James, the same "relation to the great rolls of the strata, that the ripple on the surface of the waves "bears to the heavy ocean swell," &c.—Ramsay, Mem. Geol. Survey, Great Britain, vol. 1, p. 315.

§ Mem. Geol. Surv. Gt. Britain, vol. i. p. 214.

demonstration. He states,* that in Westphalia "is a fine-" grained micaceous rock, occasionally silicious, in which no "fossils, except fragments of plants, have been detected. This "sandstone seems to occupy the place of the lower shale of the "South of England, of the yellow sandstone of Ireland, and of "the lower coaly sandstone of Scotland; for, like them, it is "immediately covered by the carboniferous limestone, or its "equivalent, often in a state of chert or petro-silex, with Posi-"donomya Becheri and Goniatites crenistria. The rock which "next succeeds is, as before said, the distinct equivalent of the "British millstone grit; like which, it underlies the great pro-"ductive coal-fields." The South Wales coal-field seems to have extended originally much further north†; and in a western direction probably was united with the coal-fields of Ireland. Later experience seems to confirm more fully still the connection of the British carboniferous formations with each other, and with those referred to on the continent. On a short examination of this and the Devonian series in Westphalia and Belgium a few months since, we noticed an iron-ore of marked character, found in the lower limestone shales in those districts, and largely used at the different ironworks. It was quite different from any known in this country. On returning home, after a few weeks careful search, the same ore was found in the same geological position in South Wales. (Description, page 217.)

Mr. Warington Smyth, tracing the lowest bed of workable coal above the "Farewell Rocks" in Yorkshire, Derbyshire, Lancashire, and other districts, under which an indurated siliceous clay or rock of marked character, penetrated by roots of stigmaria, is always found, and known there by the local term of "*Ganister*" Rock, on examination finds the same bed in the South Wales coalfield.

The same persistency of this bed has been also long observed in the South Wales coalfield, but never before connected with the northern coalfields. The coal above it is well known in this coalfield under different names.‡ In the ironstone shales above this coal, Mr. Salter also finds fossil remains of like characters as found in the same position in the Coalbrookdale coalfield.

Below this a series of beds also is found, which, although very thin at the eastern part of the coalfield, as we proceed to the west become of much importance, and yield large quantities of

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* Siluria, p. 376 et seq., where this important and interesting subject is fully dealt with.

† Mem. Geol. Surv. Gt. Britain, vol. i. p. 314 et seq.

‡ It is known at the different works as follows :—

	ft.	in.		ft.	in.
Pontypool Little Coal - -	1	6	Ebbw Vale Bottom Vein -	2	0
Farteg Brass Coal - -	1	0	Rhymney Rough Pin Coal -	1	4
Blaenafon Engine Coal - -	2	4	Dowlais Lumpy Vein	1	3
Nantyglo Big Vein - -	1	6	Hirwain Knobby Vein	1	6
Beaufort Big Vein - -	1	6	Onllwyn Cnapog Coal -	1	6
Blaineau Little Vein - -	2	0	Yniscedwin Clas-Fach Coal -	2	6

Dr. G. P. Bevan, Geologist, vol. 3. p. 98.

ironstone. The "*Rosser Veins*" are those now most worked.* Below the "Farewell Rock," as we proceed westward, are also found thin seams of coal and deposits of ironstone. These have not yet been carefully explored, but they are very persistent, and, so far as at present known, abound more than the higher measures with fossil remains of early life.

The breaking-up and denudation of this vast coal field has been most ably commented upon by Sir H. De la Beche, Sir R. Murchison, Professor Ramsay, and others, and can only be referred to here as preliminary to a more detailed description of the iron ores.† In the great change at the termination of the Carboniferous period this trough or basin, as before shown, was formed and protected to a great extent from denudation, and now forms the South Wales coal field. The extent of this is estimated by Mr. Vivian, M.P. at 640,000 acres, and over all this area the clay ironstones we hereafter describe are interstratified with the coal. We have on the north the Silurian and Old Red Sandstones; on the south of the coal basin the Old Red Sandstones, overlaid, in patches and unconformably, by the Permian series.

The importance and extent of the iron trade of this district may be illustrated pecuniarily by the fact that one firm alone pays at the rate of nearly 3,000*l.* per day in wages. The principal manufacture in iron is railway bars; but every variety of iron,‡ and more than two thirds of all the tinned plates made in the kingdom are produced here.

The main dependence of the iron works has hitherto been upon the clay ironstones of the coal measures (argillaceous carbonates of iron); as these are, however, becoming more expensive to raise as they recede from the outcrop, other resources in the district are lately attracting attention. We will classify the iron ores of South Wales in this memoir as follows; viz.—

1st. *The Clay Ironstones found in the Coal-measures.*
2nd. *The Iron Ores of the Carboniferous Limestone.*
3rd. *The Iron Ore of the Permian series.*

---

* Section from the "*Rough Pin Coal*" to the "*Farewell Rock*" at Rhymney, made by Mr. R. Bedlington:—

	ft.	in.		ft.	in.
COAL, *Rough Pin* - -	1	8	Irregular pin - -	0	1
Carbonaceous shale - -	0	4	Argillaceous shale - -	2	8
Hard argillaceous shale ("*Ganister Rock*") - -	4	0	*Upper Rosser Vein*, 2 inches to	0	$2\frac{1}{2}$
Pin of ironstone (sometimes balls of 4 inches) - -	0	1	Argillaceous shale - 2 ft. to	2	3
Argillaceous shale - -	4	0	Soft shale (holing) - -	0	$6\frac{3}{4}$
Irregular pin - -	0	1	*Lower Rosser Vein* (average) -	0	12
Argillaceous shale - -	3	0	Argillaceous shale - -	2	$\frac{1}{2}$
Pin - -	0	1	Dark argillaceous shale (holing) - -	0	1
Argillaceous shale - -	3	2	Farewell Rock - -		

† De la Beche, Mem. Geol. Surv. Gt. Brit. vol. i. p. 157.; Murchison, Siluria; Ramsay, Mem. Geol. Surv. Gt. Britain, vol. i. p. 297 et seq.

‡ A list of these works may be found in the Mineral Statistics of the Geological Survey by Mr. Robert Hunt.

The Lias, the Old Red Sandstone, and the Silurian series have hitherto been so imperfectly examined on this point as to give very insufficient data; but it is very probable, from the observations made, that iron ores may be found in these.

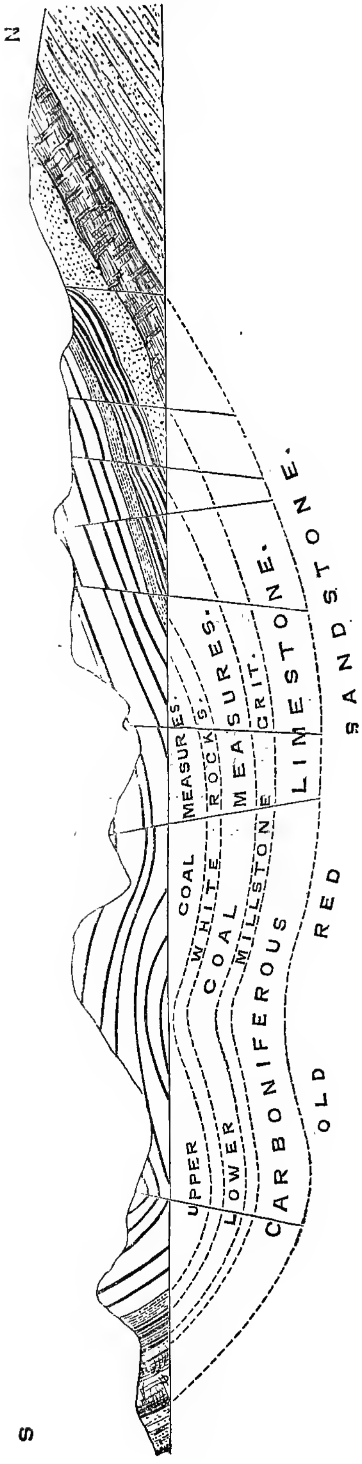
1st. *The Clay Ironstones found in the Coal-measures.*

Observation and experience show us that the Coal-measures of South Wales must be divided into two series, which we may call here the *upper* and *lower* series. These are separated over the whole coal field by thick strata of hard silicious rock, sometimes passing into a silicious conglomerate, known locally under the name of the "*Cockshute*" or "*White Rocks.*" The hardness of these rocks, and the water they yield, are always formidable hindrances in sinking through them.

The lower series are often called the "*iron-bearing measures*," and in these the great bulk of the iron and coal beds are found. The coal in this series is bituminous at the eastern outcrop, and gradually changes westward, until, after passing the great dyke or fault in the Vale of Neath,* it becomes anthracite. The upper series contains few iron ores. The coals in this are everywhere bituminous, even in the localities where anthracite coal exists below, as in the Swansea district, &c. The rocks in which these upper iron and coal seams are imbedded are mostly micaceous sandstones, known locally as the "*Pennant Rocks.*" The upper or Pennant series occupies only the higher strata of the coal basin. (See Fig. 1, partly made from No. 11, Horizontal Section of the Geological Survey of Great Britain.)

* Geological Survey, Map No. 36.

FIG. 1.



SECTION OF THE COAL-MEASURES OF SOUTH WALES.

The lower or iron-bearing measures extend over the whole coalfield, and the principal beds of ironstones are found in the lowest strata. The ironstones are on the average richer in yield of iron on the east, but they increase in thickness as we go westward, and at the same time become poorer.*

At the eastern end of the basin, which is the great iron-making district, the south outcrop dips very rapidly, often at an angle of 30 to 45 degrees, whilst on the north outcrop the dip is only from 5° to 7 degrees. This has enabled a large extent of work to be won by "levels" or galleries opening from the valleys, and at first induced the establishment of works there. Many of these levels are now working out, and sinkings have to be made to the "*deep*." This makes little difference in the cost of the *coal*, but it is generally admitted that the cost of the "*mine*" or ironstone is seriously increased: the shales become harder in depth, and adhere more tenaciously to the mine, and larger stocks must be kept to "*weather*" (*i.e.* to allow the shale to separate from the mine by the action of the atmosphere).

The highest part of the basin in which ironstone profitably workable has yet been found is a bed in the form of "*black band*,"† occurring on top of the Mynyddysllwyn seam of coal. The principal workings opened on this are by Messrs. Latch and Co. in the Rhymney Valley. The bed is irregular, sometimes several feet in thickness, and of the same general character as the "black bands" of Scotland, occurring in small basins, and often running out altogether.

The next bed of ironstone occurs over the coal known on the north outcrop as the "Old Man's" coal, and Gwr-hyd Coal, Dowlais, on the south outcrop as the Charcoal Seam at Abercarn, and the Rock Vein at Risca. This is also a "black band," and occurs, where worked at Abercarn, under the same conditions as the Mynyddysllwyn bed. (See Analysis, No. XXIII.) A considerable quantity has been raised, and it works well in the furnace.

These two irregular beds are the only workable seams yet found in the upper series.

The lower series (or "*iron-bearing measures*") contain so many beds of ironstone alternating with the coals and shales, that we can only attempt here to describe those now used in actual working for the manufacture of iron; and as these are not persistent over the whole coal field, and a very large portion of this coalfield is yet quite untried ground, this description

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* Following these lower beds of ironstones into Ireland, we find great deposits. In Limerick the cliffs on the coast near the mouth of the Shannon are mostly the lower ironstone beds, and from the beach millions of tons may be gathered, prepared by the wash of the Atlantic; the average yield of iron is, however, only 19·5 per cent. from specimens we have taken *in situ*.

† This term is applied to the argillaceous ironstones which contain sufficient carbonaceous matter to calcine themselves when fired, without any addition of fuel.

must be necessarily incomplete, but may be again added to as the resources of the district are developed. Some of the ironstones show, through a large part of the district, such marked likeness in lithological and mineralogical points as to leave no doubt of their connection as continuous beds; for instance, the "Three-quarter balls," in all the eastern part of the coalfield, are found to abound in fissures and cavities which contain needle-shaped crystals of sulphide of nickel (Millerite), Hatchettine, quartz crystals, calc-spar, and spathose iron ore; and the cavities are often filled with water of a saline taste.

But the evidence we have to depend most upon, to identify them certainly, is the fossil remains of these beds. Until recently they were supposed to contain no vestiges of animal life; this, however, was a mistake.*

As the ironstone measures are remarkably regular and full in the Ebbw Valley, and it is the only place hitherto where a good palæontological examination has been made, we take this section to illustrate the ironstone measures as yet developed. The description gives facilities for research in other parts of the district, which, if followed up, will be not only of scientific interest, but of much practical value.

SECTION of STRATA in the EBBW FAWR VALLEY, MONMOUTHSHIRE. (By Mr. W. ADAMS.)

Description of Strata.				Thickness of Strata.		
		ft.	in.	Yds.	ft.	in.
"PENNANT ROCKS."						
Surface ground				1	1	3
Rock				32	2	1
Clod				8	0	0
Rider				0	1	0
Clod				13	0	10
Rock				1	0	0
Clod				12	2	8
COAL, *Mynyddysllwyn Vein*:	Coal	3	0	2	0	5
	Clod	0	10			
	Coal	2	7			
Ground (not proved				58	2	6½
Rock				39	1	8
Clod				2	0	0
Rock				3	0	3
Clod				0	2	0
Rock				17	2	7
Clod				2	0	9
Rock				33	1	0

* About twenty years ago we found some fossil remains of annelids at Nant-y-glo, in the "Black Pins;" they were at once recognized, but at the time had no further attention. This work of research was, however, taken in hand seriously by Mr. Wm. Adams, of Ebbw Vale, who, by himself, for a long time followed the subject until he brought it into notice. His collection, with some specimens from his coadjutors in the last few years, Dr. Bevan and Mr. Needham, and also Messrs. Martin, Lucas, and Bedlington, forms the basis for the palæontological description in his memoir by Mr. SALTER.

			Yds.	ft.	in.
		in.			
COAL	Coal	4	0	0	9½
	Clod	1½			
	Coal	4			
Fire-clay			3	1	2
Rock			2	2	4
Clift			2	0	0
Rock			33	1	2
COAL			0	0	9
Fire-clay			1	0	6
Marl			5	0	8
Blue rashes			6	0	2
Black rashes			0	0	4
COAL			0	0	3
Soft fire-clay			0	0	10
Hard fire-clay			0	1	9
COAL			0	0	9
Fire-clay			0	0	5
14. Black shale, with black band and fossil shells			2	1	10
Blue rock			6	0	6
Black band			0	0	6
Blue rock			5	1	0
Beddy rock			1	0	1
COAL, *Troed-y-rhiw clawdd*			0	2	4
Fire-clay			0	1	0
"COCKSHUTE" or "WHITE ROCKS."					
Sandstone rock			7	2	0
Sandy marls; red, blue, and green coloured			8	2	0
Red and green marl			9	0	10
Sandstone rock			1	1	8
Rock			0	2	4
Very hard pebbly rock (Cockshute)			0	2	6
Small jointy rock			0	1	9
Sandy fire-clay			0	0	9
Light coloured fire-clay			1	1	9
Rather soft mine ground			3	1	0
COAL			0	1	2
Fire-clay			0	0	7
Sandy rock			3	2	6
Grey sandy rock			1	0	7
Red sandy marl			2	0	9
Rock (blue colour in these beds)			1	2	6
Sandstone rock (very hard)			1	1	6
Pudding-stone rock			2	0	0
Red marl			1	0	4
Yellow sandstone rock			2	0	10
Red marl			1	1	0
Grey rock			3	0	10
Red marl			0	0	2
Bed of rock			0	1	2
Mine ground, with sandy balls			1	0	2
Bed of rock			0	0	4
Fire-clay			0	1	2
Red marl			2	1	3
Black shale			0	0	8

Thickness of Strata (Yds. ft. in.)

	Thickness of Strata. Yds.	ft.	in.
Red marl	1	1	1
Blue sandstone rock	1	0	10
Red marl	0	2	3
Blue sandstone rock	0	1	5
Brown sandstone rock	0	1	4
Blue rock	0	1	8
Black shale ground	0	1	0
Sandy fire-clay	1	1	0
Red marl	1	0	10
Blue rock	0	1	8
Red marl	5	2	0
Brown sandy rock	0	1	6
Ground (not proved)	33	1	3
Strong shale	3	1	0
COAL	0	1	6
Fire-clay	0	2	0
Shale	6	0	0
Rock	0	1	5
Shale	4	1	7
Rock	13	2	3
Shale	0	2	10
COAL	0	1	2
Fire-clay	0	1	6
Rock, with beds of shale	14	1	3
Rough fire-clay	1	1	0
Strong mine shale	6	2	0
Shale	1	0	0
COAL	0	0	10
Shale	1	1	0
Rock	10	0	0
Very strong shale	5	0	0
Ironstone	0	0	2
Shale	0	1	4
Ironstone (pin)	0	0	1½
Shale	0	2	6
Upper Pins ground (containing 3 pins, 4½ inches of Ironstone)	1	0	4½
Shale	1	0	0
Grey rock	4	0	0
Strong mine ground	2	0	0
Black shale, with balls of Ironstone	1	0	0
COAL, *Old Man's*	0	2	4
Fire-clay	0	1	6
Hard sandy fire-clay	0	1	11
Black clay	0	1	5
Grey rock	1	1	0
Sandstone rock	4	1	6
Shale	1	1	10
Balls of Ironstone	0	0	2
Shale	0	2	0
Black band	0	0	5½
Rough fire-clay	1	1	6
Balls of Ironstone	0	1	0
Rough fire-clay	1	0	6

		Thickness of Strata.		
		Yds.	ft.	in.
	Balls of Ironstone	0	0	6
	Shale	1	1	6
	Vein of Ironstone	0	0	6
	Hard shale	4	2	3
	Shale	3	0	9
	Shale and fire-clay	7	0	6
	Grey rock (good building stone)	10	0	0
	Fire-clay	1	0	0
	COAL	0	0	10
	Shale, fire-clay, small beds of rock, &c.	35	1	9
	COAL, *Court*	0	2	0
	Thin beds of rock and shale	7	0	0
	Fire-clay	1	2	9
	Balls of Ironstone	0	0	3
	Shale, containing pins of Ironstone, 4 inches thick	3	0	6
	Shale	3	0	0
13.	Shale, containing *Soap Vein Mine*, about 3 inches thick, with fossil shells (Anals. LXVI., LXVII.)	1	2	0
	COAL	0	1	0
	Shale, mixed with beds of rock	6	2	0
	COAL	0	1	0
	Shale	2	1	6
	COAL	0	1	0
	Hard rock	2	2	0
	Shale	1	1	6
12.	*Black Pins Mine* ground (Anals LII., LVI., LXIII.)	10	0	0

	inches.	
Upper Black Pin	3	Fossil shells.
Pin Harry Walter Lewis	0½	
Pin Ammai	1½	
Red Pin	1½	
Upper Rachwen	1½	
Lower „	1	
Upper Holkin	2	
Lower „	1	
Pilson	1½	
Brown Vein	2½	
Chance Pin	0½	
Black Pin	1½	
Bottom Vein	4	

		Yds.	ft.	in.
	Soft shale	0	2	0
	COAL	0	0	4
	Shale	13	1	0
	COAL	0	0	6
	Shale	0	1	0
	Fire-clay	1	0	0
	Rock binds	2	2	0
11.	Shale with Ironstone (*Ell Balls*)	1	1	0
	COAL, *Ell*	1	0	10
	Dark soft clod and rashes	2	1	2
	Dark fire-clay	0	1	3
	Soft clod	0	0	10
	COAL, *Big Vein*	1	2	3
10.	Soft clod	0	1	10

				Thickness of Strata.	
			Yds.	ft.	in.
	Hard mine ground, with small balls of Ironstone		1	2	3
	Strong mine ground, containing *Three-quarter Balls* (Anals. LI.)		1	0	1½
	Mine ground		0	2	9
	Mine ground		0	1	1
9.	Soft clod, with fossil shells		0	0	7
	COAL, *Three-quarter*		1	0	2
	Soft clod		0	0	9
	Hard fire-clay		3	0	0
	Dark slanty mine ground (slaty cleavage)		15	0	8
	Ironstone		0	0	3
	Curly mine ground, with balls of Ironstone		3	0	0
	Mine ground		1	1	3
	Rock		0	1	2
	Hard mine ground		0	1	6
	Dark fire-clay		1	1	6
		inches.			
	COAL	Coal - 6			
		Black clod - 6			
		Coal - 3			
		Clod - 1	0	2	5
		Coal - 3			
		Clod - 7			
		Coal - 3			
	Clod		0	0	8
	Fire-clay		0	2	0
	Hard mine ground		0	2	1
	COAL		0	0	5
	Hard mine ground		0	1	2
	Rock		0	0	10
	Hard mine ground, with balls of Ironstone		1	2	3
	Hard mine ground		0	2	9
	Rock		0	0	6
	Hard ground, with rough balls of Ironstone		1	0	7
	Rock		0	1	0
	Fire-clay		1	0	0
	COAL		0	0	11
	Fire-clay, with balls of Ironstone		0	2	6
	Hard fire-clay		0	2	6
	Hard mine ground		0	2	7½
	Black clod		0	1	0
	COAL		0	2	6
	Soft clod		1	0	6
	Mine ground		1	1	4½
		inches.			
	COAL	Coal - 1½			
		Clod - 2			
		Coal - 7	0	1	1½
		Clod - 2			
		Coal - 1			
	Dark fire-clay		1	0	10
	Rock, intermixed with mine ground		1	0	1
	Black clod		0	0	7
	Hard mine ground		0	2	11

	Stratum	Component	ft.	in.	Yds.	ft.	in.
					Thickness of Strata.		
	Mine ground, containing 1 vein and 2 pins of Ironstone: *Gough's Mine*				1	2	11
	Dark mine ground				1	0	0
	Hard ground, with balls of Ironstone				1	2	0
8.	Hard mine ground, with fossil shells				1	0	9
	Black clod				0	0	3
	COAL, *Bydylog*	Coal with Brass	2	1½	1	0	3½
		Clod	0	0½			
		Coal	0	1½			
		Clod	0	1½			
		Coal	0	4			
		Clod	0	0¾			
		Coal	0	4			
		Clod	0	0¼			
		Coal	0	1½			
	Soft clod				0	1	10
	COAL				0	0	9
	Mine ground				1	1	0
	COAL				0	0	7½
	Hard mine ground				2	0	6
	Hard mine ground, with rock				0	1	10
	Ironstone				0	0	2
	Hard ground and rock				0	2	0
	Mine ground				1	0	11
	Upper Darren Mine				0	0	3½
	Mine ground				0	0	4
	Ground, with balls of Ironstone				1	0	0
	Ground, with balls of Ironstone				0	1	6
	Mine ground				0	1	0
	Ground, with balls of Ironstone				0	1	6
	Ground, with fossil shells				0	0	2
	COAL				0	1	4
	Black clod				0	0	3
	Soft holing				0	0	2
	Hard fire-clay, with small balls of Ironstone				0	2	11
	Hard ground, with small balls of Ironstone and fossil shells				0	1	3
7.	Black hard clod, with fossil shells				0	0	10
	Rock, with shells				1	2	10
	Rock				1	2	10
	Mine				0	0	2
	Rock				1	2	0
	Rock				0	1	9
	Mine ground				1	2	7
	Hard mine ground				0	2	0
	Ground, with balls of Ironstone				1	1	0
	Mine ground				1	0	10
	Pin of Ironstone				0	0	1½
	Mine ground				0	1	9½
6.	Small pin of Ironstone				0	0	1
	Mine ground				0	1	9
	COAL, *Engine*	Coal	2	0	1	1	4
		Fire-clay	1	0			
		Coal	1	4			

			Thickness of Strata. Yds.	ft.	in.
Hard fire-clay, with balls of Ironstone			3	1	0
Coal, *Gloien coch bach*	Coal	ft. 1, in. 3			
	Clod	0 6	1	0	5
	Coal	1 10			
Soft fire-clay			0	2	6
Black clod			0	1	1
Coal	Coal	ft. 0, in. 8			
	Clod	0 4	0	2	0
	Coal	1 0			
Hard fire-clay, with balls of Ironstone			1	2	6
Coal			0	1	3½
Dark clod			0	0	8
Rock, with a large quantity of gas			1	2	3
Very hard mine ground, with rock			2	0	0
Ground, with balls of Ironstone			0	1	4
Mine ground			1	1	0
Black clod			0	1	0
Coal			0	1	0
Hard rough mine ground			1	0	0
Mine ground, with little pins			1	0	7
Balls of Ironstone			0	0	4½
Mine ground			1	1	6
Very hard mine ground, with irregular balls of Ironstone			1	0	0
Mine ground			1	0	0
Black clod, with irregular balls of band			0	1	0
Black clod			0	2	6
Dark fire-clay			0	2	4
Coal, *Yard*	Coal	ft. 1, in. 10			
	Clod	0 9	1	0	8
	Coal	1 1			
5. Dark fire-clay, changing in some places to Black Band, with fossil shells in Ironstone on top of the Coal (Anal. LVII.)			0	2	11
Coal, *Old*	Coal	ft. 2, in. 6			
	Clod	0 6	2	0	8
	Coal	3 8			
Spotted vein rock			1	2	6
Mine ground			0	0	10
Mine ground			0	1	10
Hard mine ground			1	1	2
Mine ground			0	0	6½
Mine ground (Spotted Vein)			0	1	1
4. *Spotted Vein Mine* (Anals. L. LIV.)			0	0	3
Mine ground			0	1	0
Holing			0	0	1
Dark ground			0	1	0
Black holing			0	0	4
Hard ground, with small balls of Ironstone			1	1	0
Hard clod			0	1	6
Very hard clod			0	1	6

	Thickness of Strata.		
	Yds.	ft.	in.
Rock	1	1	0
Mine ground	1	1	1
Ironstone (vein)	0	0	4
Mine ground	1	0	6
Mine ground	0	2	5
Balls of Ironstone	0	0	2½
Mine ground	0	0	6
Ironstone (vein)	0	0	2
Mine ground	2	0	0
Ironstone (vein)	0	1	0
Mine ground	2	1	0
Red Vein: Top Vein Mine (Anals. LIX. LX. LXI. LXII.)	0	0	4
Mine ground	0	2	6
3. Ironstone (irregular)	0	0	2½
Mine ground	0	2	8
Spotted Pin (*Pin Bryth*)	0	0	2½
Mine ground, with fossil shells	0	2	8
Black balls (small and sandy)	0	0	3
Black mine ground, with small balls of Ironstone	0	1	2
Holing	0	0	4
Shale	0	2	7
Blue Vein Mine (irregular)	0	0	3
Shale, with fossil shells	1	2	9
Balls of Ironstone	0	0	3
Shale	1	2	3
Balls of Ironstone	0	0	4
Shale	1	0	0
Big Vein Mine, Top Vein (Ironstone)	0	0	2
Shale	0	1	9
Holing Pin (Ironstone)	0	0	1½
Shale	1	0	0
Bottom Course (Ironstone)	0	0	2
Shale	0	2	3
Nappwg Pin (Ironstone)	0	0	1½
Shale	0	2	0
Shale	0	1	0
Pin Garrw	0	0	1½
2. Shale, with fossil shells and fish remains	0	2	0
COAL, *Bottom Vein*	0	2	0
Fire-clay	0	1	0
	779	2	2½

Farewell Rock.*

1. Rosser Vein Beds (Anals. LXVIII.)
   Millstone Grit.

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* As we proceed westward from this place a new series of the lower measures is introduced, and forms an important line of separation between the "Farewell Rock" and the Millstone Grit overlying the Limestone.

2nd. *The Ironstones of the Carboniferous Limestone.*

These ores are at present very partially examined in this district: they can be classed as *veins* and *beds*. The first are known to exist by specimens taken from the outcrop, at different points on the south anticlinal line of the coal field, from near Pontypool to Lydstep Point in Pembrokeshire. These veins are, however, worked extensively at only one place, the Pentyrch Works in the Taff Valley; the sheet iron and tin plates made at these works have long been celebrated as amongst the first brands in the kingdom. The veins of iron ore occur here in nearly vertical fissures, piercing through the limestone, but with an underlay of 3 to 7 degrees to the south.

We know at present of only one bed of iron-ore in the limestone, and this has been already referred to as similar to one in Belgium and Westphalia. This bed, situate in the Lower Limestone Shales, is made up entirely of encrinital remains; these habitants of an ancient sea seem to have collected in some quiet spots, out of the reach of the currents, and to have had the power of secreting iron to a great extent, with the lime necessary for their support. No. LXVIII. gives an analysis of the ore as worked at Whitchurch, in Glamorganshire; and tracing the same bed west and east, it becomes gradually changed into an encrinital limestone. The conglomerate beds, which form the top of the Old Red Sandstone, (and are often called locally the "Lower Millstone Grit" on the north outcrop, and attain there a thickness of fully 200 feet), are entirely absent here. Further search will probably lead to new discoveries of this ore.

3rd. *The Iron Ores of the Permian Series.*

Sir H. De la Beche had long since observed that the lower bed of the Permian series occurred in some places as Hæmatite iron ore; he also pointed it out as occurring unconformably over the coal measures near Llanharran, in Glamorganshire.*

This deposit seems to occur only locally, and generally in hollows or basins, where it would be protected from the wash of the Permian sea. One of the basins now largely worked, at Mwyndy, near Llantrissant, seems to contain a great quantity of iron-ore; the bed assumes a wedge-like shape at the outcrop, and thickens as the basin is opened out to the deep. The annexed sketch will give some idea of its present appearance. The scale is about sixty yards to one inch.

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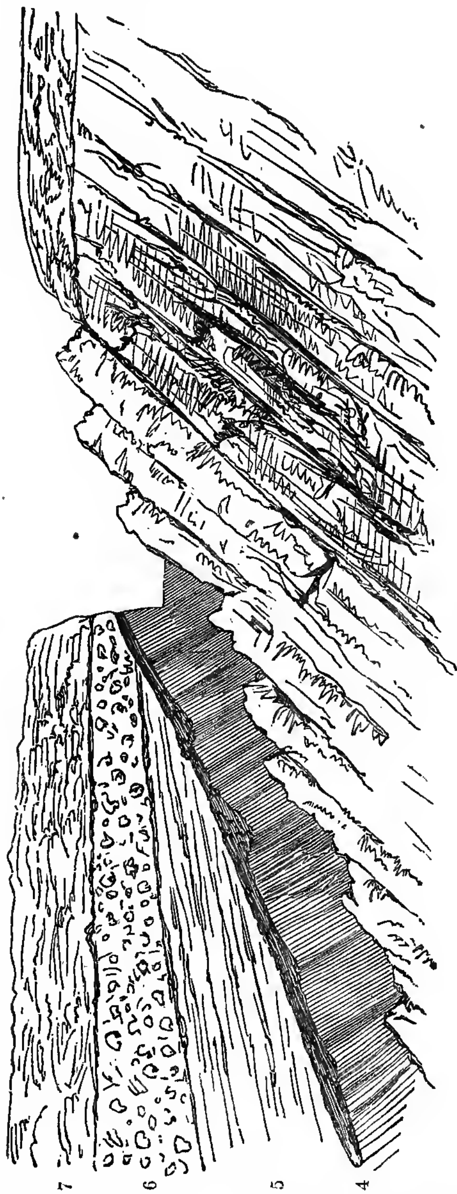
* Report on the Geology of Cornwall, Devon, &c. pp. 196, 197. Memoirs of the Geological Survey of Great Britain, vol. i. p. 264. Geological Survey of Great Britain; horizontal sections, sheet 10, section 4.

SECTION AT MWYNDY BY MR. CHARLES H. WARING.



1 Carboniferous Limestone.
2 Dolomitic Limestone.
3 Compact Hæmatite Iron Ore.
4 Hydrated Oxide of Iron.
5 Marl and Clay.
6 Calcareous Conglomerate.
7 Debris.

Analysis No. LXXIX. shows the quality of the ore. This place had been extensively worked in centuries past, and forgotten. Leland, in his Survey, states, "There are two faire parkes by south "of Llantrissant now unimpalid and without deere. There is "yren now made in one of these parkes named "'Glinog.'"*

* Leland's Itinerary, 1533 to 1540.

This is confirmed by the late opening of the old workings, and the tools and other relics found in them. This same deposit of iron-ore is found, under the like conditions, over an area of several miles to the west of the point here described. Again, at Gwar Coch, about two miles north of Porth Caul, we have the same deposit; it lies here over the limestone, and contains a large proportion of manganese. Some specimens we tested contained 35 per cent. of manganese; this almost gives it the character of a manganese ore. The bed, where opened here, is nearly five feet thick, and seems more regular than it is generally found in this district. It is remarkable that these ores only occur where the Carboniferous Limestone has been worn down to the level of the Permian sea, and the veins of iron-ore in this limestone have, of course, been broken up at the same time. The iron veins of Pentyrch continued along the ridge opposite Llantrissant; and this ridge, once broken up by the action of the sea, would allow the heaviest parts to deposit at the lower level; and over this we find thick beds of Limestone Conglomerate, not rounded or water-worn, but sharp and pointed, as if forming the *talus* of a sea beach, where the tide had gradually undermined the rocks of the coast. Nearly the like conditions obtain on the opposite coast of the Bristol Channel, and were also first observed by Sir H. De la Beche.* These deposits are since found to be in the immediate locality of large veins of iron-ore worn down by the action of the Permian sea.

The iron ores of South Wales are not yet developed so rapidly as to satisfy the requirements of the trade. Nearly 400,000 tons per annum of iron ores are imported from the Lancashire and Whitehaven districts in the North of England, and also large supplies are obtained from the South and West of England, Spain, Elba, and other foreign parts. The superior quality of the *coal*, for smelting purposes, seems to give this district an advantage which compensates for the want of very cheap iron ores. The iron ores in the South Wales district are not yet fully understood and developed; but the stubborn fact remains, that with 25 cwts. of raw coal they can, and do when properly used, make a ton of pig iron.

The subject of perhaps most interest in this short memoir is the plainer elucidation of the variety of species of organic remains in the different beds of iron ore. Already this seems to enable us to some extent to connect palæontologically iron stone measures in other coal fields with those of this district. My friend Mr. Salter having taken this work in hand, no doubt much progress will now be made in it. We may also hope to follow the like course of investigation at some future time with the coal measures; much room remains for this, and it is a field that already promises very interesting work.

The advantages of education are now also beginning to be well appreciated. The largest firm in the district, before referred to, have lately, at a cost of nearly 6,000*l.*, established, in addition

* Report on the Geology of Cornwall, Devon., &c., p. 197.

to their excellent schools, a museum and reading rooms, of which all the workmen can avail themslves. Many other works have followed this example.

L.—SPOTTED VEIN MINE,* BLAENAFON.

(By A. DICK.)

(No. 5, marked No. 4 of the Illustrated Catalogue.)

Specimens in Museum of Pract. Geol., Wallcase No. 50.

Analysis by Method No. III.

	grs.
Water, hygroscopic and combined:—	
44·01 grs. of ore lost of water at 100° C.	0·13
And gave of water at a red heat	0·29
By the action of hydrochloric acid—	
18·68 grs. of ore gave of—	
Insoluble residue	2·79
Manganoso-manganic oxide	0·21
Alumina	0·09
Sulphate of lime	0·74
Pyrophosphate of magnesia	1·56
The insoluble residue gave of—	
Silica	1·82
Alumina	0·81
Peroxide of iron	0·08
Pyrophosphate of magnesia	0·10
31·08 grs. of ore gave of organic matter	0·19
31·28 grs. of ore gave of chloride of potassium	0·28
Phosphoric and sulphuric acids, and bisulphide of iron:—	
27·68 grs. of ore gave of—	
Pyrophosphate of magnesia	0·16
Sulphate of baryta (from sulphates)	trace.
Sulphate of baryta (from bisulphide of iron)	0·77
25·75 grs. of ore gave of carbonic acid	8·11

Iron, by standard solution of bichromate of potash:—

Standard, 1 gr. of iron = 8·45 cub. cent. of solution.

	Weight of ore.	Cub. cent. of solution.	Per cent. iron.
I.	9·05	26·9	35·19
II.	11·34	33·5	34·95

Results tabulated.—Ore dried at 100° C.

Protoxide of iron	45·22
Protoxide of manganese	1·05
Alumina	0·58
Lime	1·63
Magnesia	3·04
Carbonic acid	31·58
Phosphoric acid	0·38
Sulphuric acid	trace.
Bisulphide of iron	0·71
Water	0·66
Organic matter	0·64
Insoluble residue	14·50
	99·99

* The word "mine" is commonly used in South Wales for ore.

Insoluble Residue.

Silica - - - - -	9·46
Alumina - - - -	4·20
Magnesia - - - -	0·20
Potash - - - - -	0·56
	14·42
Iron, total amount - - -	35·48

Minute traces of copper and lead were detected in the hydrochloric acid solution of 905 grains of ore.

LI.—Three Quarter Balls, Blaenafon.

(By A. Dick.)

(No. 3 of the Illustrated Catalogue.)

Analysis by Method No. III.

	grs.
Water, hygroscopic and combined:—	
33·95 grs. of ore lost of water at 100° C. - -	0·12
And gave of water at a red heat - - -	0·36
By the action of hydrochloric acid—	
13·43 grs. of ore gave of—	
Insoluble residue - - - - -	3·70
Manganoso-manganic oxide - -	0·11
Alumina - - - - - -	0·065
Sulphate of lime - - -	0·35
Pyrophosphate of magnesia - - -	1·66
The insoluble residue gave of—	
Silica - - - -	2·67
Alumina - - - - - -	0·82
Peroxide of iron - - -	0·09
Sulphate of lime - - -	0·12
25·36 grs. of ore gave of organic matter - -	0·20
31·01 grs. of ore gave of chloride of potassium -	0·35
Phosphoric and sulphuric acids, and bisulphide of iron:—	
29·32 grs. of ore gave of—	
Pyrophosphate of magnesia - - - -	0·08
Sulphate of baryta (from sulphates) - - -	trace.
Sulphate of baryta (from bisulphide of iron) - -	0·13
26·36 grs. of ore gave of carbonic acid - - -	7·18

Iron by standard solution of bichromate of potash:—

Standard: 1 gr. of iron = 8·45 cub. cent. of solution.

	Weight of ore.	Cub. cent. of solution.	Per cent. iron.
I.	10·10	24·0	28·10
II.	11·00	25·9	27·87

Results tabulated.—Ore dried at 100° C.

Protoxide of iron	36·10
Protoxide of manganese	0·76
Alumina	0·48
Lime	1·07
Magnesia	4·52
Carbonic acid	27·33
Phosphoric acid	0·18
Sulphuric acid	trace
Bisulphide of iron	0·11
Water	1·06
Organic matter	0·79
Insoluble residue	27·58
	99·98

Insoluble Residue.

Silica	19·90
Alumina	6·09
Peroxide of iron	0·60
Lime	0·35
Potash	0·71
	27·65

Iron, total amount	28·55

Minute traces of copper and lead were detected in the hydrochloric acid solution of 870 grains of ore.

LII.—Black Pins, Blaenafon.

(By A. Dick.)

(No. 2, marked No. 1 of the Illustrated Catalogue.)

Analysis by Method No. III.

	grs
Water, hygroscopic and combined:—	
33·75 grs. of ore lost of water at 100° C.	0·08
And gave of water at a red heat	0·41
By the action of hydrochloric acid:—	
10·90 grs. of ore gave of—	
Insoluble residue	1·89
Manganoso-manganic oxide	0·125
Alumina	0·065
Sulphate of lime	0·765
Pyrophosphate of magnesia	1·01
The insoluble residue gave of—	
Silica	1·27
Alumina	0·47
Peroxide of iron	0·06
Pyrophosphate of magnesia	0·09
24·26 grs. of ore gave of organic matter	0·20
38·50 grs. of ore gave of chloride of potassium	0·29

Phosphoric and sulphuric acids, and bisulphide of iron :—

46·61 grs. of ore gave of—	
Pyrophosphate of magnesia	0·56
Sulphate of baryta (from sulphates)	trace.
Sulphate of baryta (from bisulphide of iron)	0·28
23·77 grs. of ore gave of carbonic acid	7·19

Iron by standard solution of bichromate of potash :—

Standard : 1 gr. of iron = 8·45 cub. cent. of solution.

	Weight of ore.	Cub. cent. of solution.	Per cent. iron.
I.	11·45	30·9	31·81
II.	10·15	27·7	32·16

Results tabulated.—Ore dried at 100° C.

Protoxide of iron	41·22
Protoxide of manganese	1·07
Alumina	0·59
Lime	2·89
Magnesia	3·38
Carbonic acid	30·07
Phosphoric acid	0·76
Sulphuric acid	trace.
Bisulphide of iron	0·15
Water	1·21
Organic matter	0·82
Insoluble residue	17·27
	99·43

Insoluble Residue.

Silica	11·60
Alumina	4·29
Peroxide of iron	0·45
Magnesia	0·30
Potash	0·48
	17·12
Iron, total amount	32·44

A minute trace of copper was detected in the hydrochloric acid solution of 900 grains of ore.

LIII.—Spotted Vein Mine (Balls), Pontypool.

(By E. Riley.)

Description.—Clay ironstone, easily scratched by a steel point ; colour, varying from light to dark brown gray ; fracture,

conchoidal. The ore is seamed with tolerably thick veins of brown spar (carbonate of iron and lime).

Analysis by Method No. I.

	grs.
Water, hygroscopic and total amount :—	
42 · 06 grs. of ore lost of water at 100° C.	0 · 17
40 · 35 grs. of ore gave of water at a red heat	0 · 47
By the action of hydrochloric acid :—	
25 · 40 grs. of ore gave of—	
Insoluble residue	3 · 98
Peroxide of iron	12 · 51
Silica, soluble in hydrochloric acid	0 · 055
Alumina	0 · 34
Manganoso-manganic oxide ($Mn_3 O_4$)	0 · 20
Carbonate of lime	0 · 865
Pyrophosphate of magnesia	1 · 72
The insoluble residue gave of—	
Silica	2 · 69
Alumina	1 · 165
Peroxide of iron	0 · 145
Sulphate of lime	0 · 115
Pyrophosphate of magnesia	0 · 10
35 · 535 grs. of ore gave of—	
Organic matter	0 · 075
Mixed chlorides of potassium and sodium	0 · 58
Chloride of platinum and potassium	1 · 48
Phosphoric acid and bisulphide of iron :—	
25 · 30 grs. of dried ore gave of—	
Pyrophosphate of magnesia	0 · 095
79 · 815 grs. of ore gave of—	
Sulphate of baryta (from bisulphide of iron)	0 · 365
I. 20 · 795 grs. of ore gave of carbonic acid	6 · 405
II. 36 · 335 grs. " "	11 · 13

Results tabulated.—Ore dried at 100° C.

Protoxide of iron	44·50
Protoxide of manganese	0·73
Alumina	1·35
Lime	1·91
Magnesia	2·47
Carbonic acid	30·92
Phosphoric acid	0·23
Silica, soluble in hydrochloric acid	0·22
Bisulphide of iron	0·11
Water, in combination	0·76
Organic matter	0·21
Insoluble residue	15·73
	99·14

Insoluble Residue.

Silica - - - -	10·59
Alumina -	4·60
Peroxide of iron -	0·50
Lime - - - -	0·18
Magnesia - -	0·14
Potash - -	0·79
Soda - - - -	0·13
	16·93
Iron, total amount - - -	34·96

A distinct trace of copper was detected in 200 grains of the ore.

LIV.—Meadow Vein Mine.

(By A. Dick.)

(No. 4, marked No. 3 of the Illustrated Catalogue.)

Analysis by Method No III.

Water hygroscopic and combined:—	grs.
37·74 grs. of ore lost of water at 100° C. - -	0·14
And gave of water at a red heat - -	0·37
By the action of hydrochloric acid:—	
10·50 grs. of ore gave of—	
Insoluble residue - - -	3·16
Manganoso-manganic oxide	0·09
Alumina -	0·025
Sulphate of lime -	0·93
Pyrophosphate of magnesia	1·06
The insoluble residue gave of—	
Silica - -	2·11
Alumina - -	0·84
Peroxide of iron - -	0·10
Sulphate of lime - - -	0·07
38·39 grs. of ore gave of organic matter -	0·44
26·35 grs. of ore gave of chloride of potassium -	0·34
Phosphoric and sulphuric acids, and bisulphide of iron:—	
24·15 grs. of ore gave of—	
Pyrophosphate of magnesia - - -	0·11
Sulphate of baryta (from sulphates) - -	trace.
Sulphate of baryta (from bisulphide of iron)	0·30
27·86 grs. of ore gave of carbonic acid - -	7·26

Iron, by standard solution of bichromate of potash:—

Standard: 1 gr. of iron = 8·45 cub. cent. of solution.

	Weight of ore.	Cub. cent. of solution.	Per cent. iron.
I.	9·58	20·4	25·19
II.	9·76	20·7	25·09

Results tabulated.—Ore dried at 100° C.

Protoxide of iron	32·44
Protoxide of manganese	0·80
Alumina	0·24
Lime	3·66
Magnesia	3·69
Carbonic acid	26·15
Phosphoric acid	0·28
Sulphuric acid	trace.
Bisulphide of iron	0·30
Water	0·98
Organic matter	1·15
Insoluble residue	30·01
	99·70

Insoluble Residue.

Silica	20·04
Alumina	7·98
Peroxide of iron	0·76
Lime	0·27
Potash	0·81
	29·86

Iron, total amount - - 26·01

Extremely minute traces of copper and lead were detected in the hydrochloric acid solution of 740 grs. of ore.

LV.—Three Cakes, Meadow Vein Mine, Pontypool.

(By A. Dick.)

Analysis by Method No. II.

	grs.
Water hygroscopic and combined :—	
40·47 grs. of ore lost of water at 100° C.	0·20
And gave of water at a red heat	0·40
By the action of hydrochloric acid :—	
20·38 grs. of ore gave of—	
Insoluble residue	5·64
Peroxide of iron	5·87
Manganoso-manganic oxide	0·24
Alumina	0·075
Sulphate of lime	4·005
Pyrophosphate of magnesia	3·15
Silica	0·05
5·06 grs. of insoluble matter gave of—	
Silica	3·39
Alumina	1·54
Peroxide of iron	0·19
Lime and magnesia	traces.
36·22 grs. of ore gave of organic matter	0·15
46·18 grs. of ore gave of chloride of potassium	0·60

Phosphoric and sulphuric acids, and bisulphide of iron :—

96·54 grs. of ore gave of pyrophosphate of magnesia	0·26
37·84 grs. of ore gave of—	
Sulphate of baryta (from sulphates)	trace.
Sulphate of baryta (from bisulphide of iron)	1·03
29·90 grs. of ore gave of carbonic acid	8·42

Results tabulated.—Ore dried at 100° C.

Protoxide of iron	26·03
Protoxide of manganese	1·09
Alumina	0·37
Lime	8·14
Magnesia	5·48
Carbonic acid	28·29
Phosphoric acid	0·17
Sulphuric acid	trace.
Silica	0·24
Bisulphide of iron	0·69
Water	0·99
Organic matter	0·41
Insoluble residue	27·35
	99·25

Insoluble Residue.

Silica	18·32
Alumina	8·30
Peroxide of iron	0·56
Lime and magnesia	traces.
Potash	0·82
	28·00

Iron, total amount	20·95

A trace of copper was detected in 600 grs. of ore.

LVI.—Black Pin Mine (Middle Pin), Pontypool.

(By E. Riley.)

Description. — Clay ironstone, easily scratched by a steel point; colour, blackish gray; fracture, sub-conchoidal; surface of fracture, rough. A very thin vein of carbonate of lime occurs in the sample analyzed.

Analysis by Method No. I.

Water hygroscopic and total amount :—	grs.
33·29 grs. of ore lost of water at 100° C.	0·20
32·355 grs. of ore gave of water at a red heat	0·55

By the action of hydrochloric acid :—

16·875 grs. of ore gave of—	
Insoluble residue	6·125
Peroxide of iron	5·03
Silica, soluble in hydrochloric acid	0·085
Alumina	0·20
Manganoso-manganic oxide (Mn_3O_4)	0·09
Carbonate of lime	0·935
(Above converted into sulphate of lime	1·27)
Pyrophosphate of magnesia	1·90
The insoluble residue gave of—	
Silica	4·60
Alumina	1·29
Peroxide of iron	0·18
Sulphate of lime	0·115
Pyrophosphate of magnesia	0·20
62·205 grs. of ore gave of—	
Organic matter	0·51
Mixed chlorides of potassium and sodium	1·36
Chloride of platinum and potassium	3·82
Phosphoric acid and bisulphide of iron :—	
16·775 grs. of dried ore gave of—	
Pyrophosphate of magnesia	0·095
61·66 grs. of ore gave of—	
Sulphate of baryta (from bisulphide of iron)	1·255
I. 18·655 grs. of ore gave of carbonic acid	4·34
II. 24·585 „ „ „	5·70

Results tabulated.—Ore dried at 100° C.

Protoxide of iron	26·98
Protoxide of manganese	0·49
Alumina	1·19
Lime	3·11
Magnesia	4·13
Carbonic acid	23·40
Phosphoric acid	0·35
Silica, soluble in hydrochloric acid	0·50
Bisulphide of iron	0·52
Water, in combination	0·78
Organic matter	0·82
Insoluble residue	36·51
	98·78

Insoluble Residue.

Silica	27·41
Alumina	7·69
Peroxide of iron	0·73
Lime	0·22
Magnesia	0·42
Potash	1·18
Soda	0·16
	37·81

Iron, total amount	21·49

A distinct trace of copper was detected in 234 grains of the ore.

LVII.—Black Band, Pontypool.

(By A. Dick.)

Analysis by Method No. II.

	grs.
Water, hygroscopic:—	
47·08 grs. of ore lost of water at 100° C.	0·29
Combined water could not be determined, owing to the lsrge amount of tarry matter evolved when the ore was heated sufficiently to expel the water combined with the clay.	
By the action of hydrochloric acid:—	
13·15 grs. of ore gave of insoluble residue	3·42
The hydrochloric acid solution and the solution of the residue gave of—	
Peroxide of iron	4·65
Manganoso-manganic oxide	0·15
Alumina	1·02
Sulphate of lime	1·22
Pyrophosphate of magnesia	1·26
Silica	2·22
21·34 grs. of ore gave of—	
Organic matter about	1·83
Chloride of potassium	0·39
Phosphoric and sulphuric acids, and bisulphide of iron —	
58·67 grs. of ore gave of pyrophosphate of magnesia	0·32
50·75 grs. of ore gaze of—	
Sulphate of haryta (from sulphates)	traces.
Sulphate of baryta (from bisulphide of iron)	0·95
35·45 grs. of ore gave of carbonic acid	8·82

Results tabulated.—Ore dried at 100° C.

Protoxide of iron	31·74
Protoxide of manganese	1·06
Alumina	7·75
Lime	3·84
Magnesia	3·51
Potash	1·12
Carbonic acid	25·03
Phosphoric acid	0·35
Sulphuric acid	trace.
Silica	16·97
Bisulphide of iron	0·48
Water	undetermined.
Organic matter about	8·50
	100·35
Iron, total amount	24·90
Clay after ignition	26·16

Traces of silver and copper were detected in 600 grs. of ore.

LVIII.—Black Band, Abercarn, Monmouthshire.

(By W. Ratcliffe.)

Description.—Colour, brownish grey; compact; containing thin seams of coal, and films of pyrites in some of the joints.

Analysis chiefly by Method No. II.

Results tabulated.

Protoxide of iron - - -	43·37
Sesquioxide of iron - - -	4·10
Oxide of manganese - - -	1·50
Alumina - -	6·05
Lime - - -	3·00
Magnesia - -	0·25
Silica - - -	2·80
Potash - - -	0·32
Carbonic acid -	30·50
Sulphuric acid (from pyrites) -	1·56
Phosphoric acid -	traces.
Organic matter - -	6·25
Hygroscopic water	0·27
Combined water -	0·31
	100·28
Iron, total amount - - -	36·49

* Cwm Celyn and Blaina Iron Works, Monmouthshire.

(Proprietors, Messrs. Levick and Simpson.)

The principal ironstones worked at this establishment are, taken in ascending order, the Red Vein, Spotted Vein, Black Pins, and Soap Vein.

The following Analyses (LIX. to LXVII.) of most of their subdivisions have been kindly contributed by Mr. Levick, for whom they were made by Dr. Noad, F.R.S.

As the details of the various measures differ, even in tracts so near together as Cwm Celyn and Ebbwvale, the following sections of the different bands are appended, giving their measurements as obtained in the workings in 1860.

Red Vein Measures.

Upper Pin -	1½ inches, of grey colour.
Red Vein -	3 to 4 in. accompanied by some 6 in. of "jack," or argillaceous stone, containing a small per centage of iron, and exhibiting "cone-in-cone" structure.

* The descriptive notes on the Ironstones of Cwm Celyn and Blaina, Dowlais, Cwm Afon, and Ystalyfera are by Warington W. Smyth, M.A., F.R.S.

Pins or Cakes,	2 to 4 in.	having numerous cracks filled with carbonate of iron and lime.
Black Mine -	3 to 4 in.	This, as well as the Red vein above, contains Hatchettine in the cracks and hollows.

These ironstones lie in about six feet of ground.

Spotted Vein.

Pins - -	7 inches.
Ground (shale, &c.)	2 feet, 3 in.
Pin - -	2 in.
Ground with balls	1 foot 10 in.

Black Pins.

	Ft.	in.	
Black Pin - -	0	4	a darker stone than most of those which follow.
Ground - -	1	2	
Yellow Pin - -	0	4	dark grey stone, breaking with very regular smooth joints.
Ground -	3	4	
Pin *ammal* -	0	3	
Ground - -	1	3	
Pin *goch* (red) -	0	2½	in shorter lenticular forms than the yellow pin.
Ground - -	2	11	
Holkin - -	0	3	
Ground - -	1	1	
Double Pins - -	0	2	
Ground - -	0	6	
Pilsen (pills) -	0	3	
Ground - -	1	8	
Grey Vein - -	0	2	
Ground - -	0	10	
Tobacco Pins -	0	2	showing a succession of thin variously-coloured laminæ.
Ground - -	0	6	
Black Pin - -	0	1	
Ground - -	1	0	
Grey Pin - - (*pin glas bach*)	0	3	

This last is accompanied by "jack," sometimes both above and below; and exhibits numerous vertical cracks or joints with crystalline Quartz and, not unfrequently, Hatchettine.

Soap Vein.

Top Mine:—

	Ft.	in.	
Vein	0	2	brownish stone, which, as well as the next below, is somewhat poor.
Ground	1	10	
Two-inch Pin	0	2	
Ground	2	1	
Tobacco Pin	0	1	thin, but excellent stone, formed of thin layers, looking like cakes of Cavendish tobacco; contains Millerite.
Ground	0	2	
Snuff Pin	0	0½	
Ground	2	0	
Bottom Mine;—			
Rashin	0	3	contains Hatchettine in the cavities.
Rashin mine ground	2	0	
Pins	0	1½	
Soap Vein Coal	1	0	

Metallic sulphides are very unusual in the ironstones of this eastern extremity of the coalfield, remarkably so as compared with the ironstones of central England. The above measures, on the other hand, contain frequently Quartz, and more rarely, but yet in comparative abundance, Hatchettine, and Millerite or sulphide of nickel, substances not observed in the analogous deposits of our Midland and Northern coal fields.

LIX.—1° Red Vein Measures.

Specimens in Museum, Wall-case No. 50.

a. Red Vein.

Loss by Roasting = 24·0 per cent.

Tabulated Results of Analysis.

Silica	8·310
Alumina, insoluble in hydrochloric acid	3·130
Alumina, soluble in hydrochloric acid	2·520
Carbonate of iron	73·790
Carbonate of lime	2·950
Carbonate of magnesia	3·800
Protoxide of manganese	0·920
Phosphoric acid	0·530
Sulphuric acid	traces.
Bisulphide of iron	0·170
Potash	0·480
Organic matter and water	2·360
	98·960
Iron, total amount	35·625

LX.—*b.* Black Vein.

Loss by Roasting = 30·7 per cent.

Tabulated Results of Analysis.

Silica -	4·600
Alumina, insoluble in hydrochloric acid -	2·000
Alumina, soluble in hydrochloric acid	3·600
Carbonate of iron - -	80·220
Carbonate of lime -	4·650
Carbonate of magnesia -	2·910
Protoxide of manganese -	1·020
Phosphoric acid	0·427
Sulphuric acid - -	trace.
Bisulphide of iron	0·123
Potash - -	not determined.
Organic matter and water -	not determined.
	99·550
Iron, total amount - - -	38·75

LXI.—*c.* "Jack" in Red Vein.

Loss by Roasting = 30·4 per cent.

Tabulated Results of Analysis.

Silica - -	8·130
Alumina, insoluble in hydrochloric acid -	2·220
Alumina, soluble in hydrochloric acid -	5·150
Carbonate of iron - -	51·120
Carbonate of lime - -	19·800
Carbonate of magnesia -	11·880
Protoxide of manganese -	not determined.
Phosphoric acid -	not determined.
Sulphuric acid -	not determined.
Bisulphide of iron	not determined.
Potash -	not determined.
Organic matter and water	not determined.
	98·300
Iron, total amount - - -	24·650

LXII.—*d.* Grey Vein.

Loss by Roasting = 28·0 per cent.

Tabulated Results of Analysis.

Silica - - - -	15·240
Alumina, insoluble in hydrochloric acid -	3·300
Alumina, soluble in hydrochloric acid -	2·700
Carbonate of iron - - -	70·500
Carbonate of lime - - -	1·980
Carbonate of magnesia - - -	3·900
Protoxide of manganese - -	not determined.
Phosphoric acid - - -	0·217
Sulphuric acid - - -	trace.
Bisulphide of iron - - -	0·119
Potash - - -	not determined.
Organic matter and water -	not determined.
	97·956
Iron, total amount - - -	34·000

LXIII.—2° Black Pin Measures.

a. Black Pin.

Loss by Roasting = 28·0 per cent.

Tabulated Results of Analysis.

Silica - - - -	12·000
Alumina (insoluble in hydrochloric acid)	4·000
Alumina (soluble in hydrochloric acid) -	1·150
Carbonate of iron - - -	71·700
Carbonate of lime - - -	2·640
Carbonate of magnesia - - -	4·230
Protoxide of manganese - - -	1·420
Phosphoric acid - - - -	0·482
Sulphuric acid - - -	trace.
Bisulphide of iron - - -	trace.
Potash - - - -	0·489
Organic matter and water - -	1·645
	99·756
Iron, total amount - - -	34·600

LIV.—*b.* Red Pin.

Loss by Roasting = 26·8 per cent.

Tabulated Results of Analysis.

Silica - - - -	15·400
Alumina (insoluble in hydrochloric acid)	5·000
Alumina (soluble in hydrochloric acid) -	3·520
Carbonate of iron - - -	57·990
Carbonate of lime - - -	3·450
Carbonate of magnesia - -	8·580
Protoxide of manganese - - -	0·640
Phosphoric acid - - -	0·750
Sulphuric acid - - -	trace
Bisulphide of iron - - -	0·241
Potash - - - - -	0·450
Organic matter and water - -	2·340
	98·361
Iron, total amount - - -	28·0

LXV.—*c.* Yellow Pin.

Loss by Roasting = 22·7 per cent.

Tabulated Results of Analysis.

Silica - - - - -	25·200
Alumina, insoluble in hydrochloric acid	8·200
Alumina, soluble in hydrochloric acid -	8·200
Carbonate of iron - - -	48·300
Carbonate of lime - - - -	1·200
Carbonate of magnesia - - -	6·000
Protoxide of manganese - - -	0·327
Phosphoric acid - - - -	0·214
Sulphuric acid - - -	trace.
Bisulphide of iron - - -	0·124
Potash - - - - -	0·389
Organic matter and water - -	1·320
	99·474
Iron, total amount - - -	23·3

LXVI.—3° Soap Vein Measures.

a. Top Soap Vein.

Loss by Roasting = 25·2 per cent.

Tabulated Results of Analysis.

Silica - - - - - -	20·000
Alumina, insoluble in hydrochloric acid -	5·000
Alumina, soluble in hydrochloric acid -	2·850
Carbonate of iron - - -	59·610
Carbonate of lime - - -	4·500
Carbonate of magnesia - -	4·800
Phosphoric acid - - -	0·424
Sulphuric acid - - - -	trace.
Bisulphide of iron - - -	0·246
Potash - - - - -	0·444
Organic matter and water - -	1·442
	99·316

Iron, total amount - - -	28·75

LXVII.—b. Bottom Soap Vein.

Loss by Roasting = 29·9 per cent.

Tabulated Results of Analysis.

Silica - - - - - -	9·540
Alumina, insoluble in hydrochloric acid -	4·460
Alumina, soluble in hydrochloric acid -	2·500
Carbonate of iron - - -	77·340
Carbonate of lime - - - -	none.
Carbonate of magnesia - -	0·900
Protoxide of manganese - -	0·530
Phosphoric acid - - - -	0·576
Sulphuric acid - - -	trace.
Bisulphide of iron - - -	0·192
Potash - - - - -	0·530
Organic matter and water - -	2·240
	98·802

Iron, total amount - - -	37·3

Dowlais, Merthyr Tydfil.

A series of the ironstones raised and smelted at these extensive works were analysed for the proprietors by Mr. Riley, and the results have been obligingly communicated by G. Clarke, Esq. one of the trustees of the late Sir John Guest, Bart.

In order to fix the position of the respective beds and to facilitate comparison with other portions of the district, the folowing detailed section of a great thickness of the coal-measures, as shown in the various Dowlais workings, has been contributed by Mr. Martin, the officer in charge of the underground operations:—

Section of the Strata at Dowlais.

Commencing at the Top of the Bargoed Pits.

	Ft.	in.
Turf	1	0
Clay	4	0
Fire-clay	5	0
Shale	8	0
Blue Rock	3	6
Black Rock	8	0
Grey Rock	1	6
Strong Cliff	33	10
Cliff	6	2
Shale	21	0
Coal	0	5
Fire-clay	3	7
Rock	4	5
Black Clod	1	10
Coal	1	3
Black Clod	0	10
Coal	0	2
Fine Fire-clay	2	7
Black Clod	1	0
Fire-clay with balls of Ironstone	6	6
Rock with Smooths	5	0
Strong Cliff	24	0
Shale with Ironstone	13	4
Coal	1	1
Fire-clay with balls of Ironstone	8	0
Shale	2	0
Ironstone	0	3
Black Clod	2	4
Coal	0	2½
Black Clod	1	0
Rock with Smooths	5	0
Shale with Ironstone	2	2

	Ft.	in.
Soap Vein:—		
Ironstone - - -	0	3
Shale - - - -	1	6
Ironstone - - -	0	1½
Shale - - - -	2	2
Ironstone - -	0	1½
COAL - - - -	1	6½
Clod - - - -	0	2
COAL - - -	0	4
Fire-clay - - - -	6	0
COAL - - - - -	0	6
Clod - - - -	0	2
COAL - - - - -	0	4
Fire-clay - - - -	1	3
Strong Rock - - - -	11	0
Cliff - - - - -	4	6
Shale with Ironstone - - -	10	6
COAL - - - - -	1	3
Fire-clay - - - -	5	0
Rock - - - - -	2	0
Cliff - - - - -	0	6
Ironstone - - - -	0	2
Cliff - - - - -	0	9
Strong Rock - - - -	12	0
Shale with Ironstone - - -	17	0
COAL - - - - -	1	4
Fire-clay with balls of Ironstone -	9	0
Black Clod - - - -	6	6
Ironstone - - - -	0	3
Clod - - - - -	2	3
Rock with Smooths - - -	5	6
Shale with Ironstone - - -	6	4
Ironstone - - - -	0	4
Shale - - - - -	18	0
Two courses of Ironstone, not regular -	0	3
Shale - - - - -	5	0
Ironstone - - - -	0	2½
Shale - - - - -	6	0
Ironstone - - - -	0	1
Shale - - - - -	0	0½
Ironstone - - - -	0	1
Shale - - - - -	3	0
Black Rock - - -	1	0
Cliff - - - - -	1	8
COAL - - - - -	0	4
Black Clod - - - -	0	6
Fire-clay with Rock - - -	8	6
Shale with Ironstone - - -	7	3

	Ft.	in.
Lower Black Pins:—		
Ironstone	0	3
Shale	1	6
COAL	1	1
Fire-clay with balls of Ironstone	8	0
Strong cliff with balls of Ironstone	21	0
Very hard Rock with Water	26	0
Shale	21	8
Yard Coal (Elled) Monmouthshire:—		
COAL	1	0
Clod	2	0
COAL	0	8
Clod	0	5
COAL	1	10
Clod	3	0
Shale	15	0
Rock	15	0
Upper 4 feet COAL	3	2
Fire-clay with Ironstone	5	7
Shale	9	0
Fire-clay	2	1
Balls of Ironstone	0	6
Cliff	18	0
Black COAL	2	0
Shale	13	0
Dowlais Big Coal:—		
Clod	2	2
COAL	0	4
Clod	0	6
Top COAL	2	8
Engine COAL	0	8
Clod	0	9
Engine COAL	0	7
Clod	0	2
Bottom COAL	3	7
Clod	0	7
Lower Engine COAL	0	6
Clod	0	3
Greack COAL	1	4
Fire-clay	0	7
Iron COAL	1	0
Shale with balls of Ironstone	6	4
Big balls	0	6
Strong Shale	6	0
Little COAL	1	0
Strong Shale	9	0
Clod	0	8
Hard Rock	17	4
Shale	8	0
Hard Rock, varying from 2 to 7 ft.	6	0
Shale	0	9
Ironstone	0	3

	Ft.	in.
Black Pin Soap Veins:—		
Shale - - - -	0	11
Ironstone - - -	0	1
Shale - - -	2	4
Ironstone - - -	0	1
Shale - - -	3	10
Ironstone - - -	0	5
Shale - - -	3	3
Ironstone - - -	0	1
Shale - -	0	9
Black Clod - - - -	0	8
Hard Cliff - - - -	12	0
Hard Rock - - - -	21	6
Black Shale - - - -	0	7
Black-band Ironstone - - -	0	2
Red Coal:—		
COAL - - -	1	6
Clod - - -	0	3
COAL - - -	0	3
Shale, with two courses of Ironstone balls	3	0
Ras Las Coal:—		
Top COAL - - - -	4	9
Clod - - - - -	0	1
Engine COAL - - -	0	5
Clod - -	0	0½
Engine COAL - -	0	4
Clod - - -	2	6
Bottom COAL - - -	3	0
Strong Shale - -	9	0
Ironstone - - - -	0	1½
Shale - - - -	1	0
Brass Vein:—		
Ironstone - - -	0	2
Shale - -	2	0
COAL - - -	2	0
Engine Coal - - -	0	6
Clod - - - - -	0	4
Very hard Shale with bands of Rock -	2	6
Little Pins:—		
Jack Pin Ironstone - -	0	2
Shale - - -	3	0
Lumpy Vein - - -	0	3
Shale - - -	2	0
Double Pin - - -	0	2
Shale - - -	0	11
Strong Pin - - - -	0	2
Shale - - -	0	10
Little Pin - - -	0	1
Shale - - -	0	11
Little Pin - - - -	0	1

	Ft.	in.
Very hard Shale - - -	3	6
Ras Las Big Vein Ironstone -	0	3
Shale - - - -	0	11
Ras Las Little Vein - - -	0	2
Shale - - - -	2	6
COAL and Clay Vein - - -	1	2
Fire Clay - - - -	2	0
Black Clod - - - -	0	9
Fire Clay - - -	0	9
Black Clod - - - -	2	9
Fire-clay - - - -	0	9
Three Coals or Clay Coals :—		
COAL - - - -	1	7
Black Clod - - -	0	2
COAL - - -	0	9
Black Clod - - -	1	2
COAL - - -	0	8
Good Fire-clay - -	4	0
Shale - - - -	3	0
Yellow Balls - - -	0	2
Shale - - - -	6	0
Yellow Balls - - -	0	2
Shale - - -	3	0
Yellow Balls - - -	0	3
Shale - - - -	3	6
COAL - - - -	1	6
Clod - - - -	0	4
Very hard Shale - - -	10	0
Blue Vein Ironstone - - -	0	4
Very hard Shale - - -	7	0
Little Vein Ironstone - - -	0	5
Little Vein :—		
Shale - - -	2	6
COAL - - - -	3	0
Fire-clay - - -	2	9
Shale - - - -	5	0
COAL - - - -	1	6
Clod - - - -	1	5
Shale - - - -	2	4
COAL - - - -	1	3
Clod - - - -	1	5
Shale - - - -	6	7
Blue above Coal :—		
Ironstone - - -	0	5
Shale - - -	3	7
Ironstone - - -	0	2
Shale - - -	1	0
Ironstone - - -	0	$1\frac{1}{2}$
Shale - - - -	4	8

	Ft.	in.
Lower Four Feet or Old Coal:—		
Top Coal - - -	2	6
Clod - - -	1	0
Middle Coal - -	2	9
Clod - - -	0	2
Engine Coal - - -	0	7
Clod - - -	2	6
Bottom Coal - - -	4	0
Clod - - -	0	9
Hard Rock - - -	6	6
Shaley Clod - - -	0	4
Spotted Vein:—(Anal. LXXI.)		
Spotted Pin Ironstone -	0	4
Shale - - - -	1	6
Pin Bryth - - -	0	3
Shale - - - -	3	2
Rider Balls - - -	0	5
Shale - - - -	3	6
Very hard Shale - - -	9	6
Yellow Vein Top Pin - - -	0	3
Yellow Veins:—		
Shale - - - -	1	8
Middle Pin - - -	0	2
Shale - - -	2	10
Double Pin - - -	0	4
Shale - - -	3	2
Red Vein:—		
Red Vein Pin - - -	0	2
Shale - - -	1	6
Little Pin - - -	0	1½
Shale - - -	1	6
Red Vein - - -	0	4
Shale - - -	3	9
Black Vein - - -	0	4
Hard Rock - - - -	5	10
Rock Vein - - - -	0	5
Shale - - - - -	3	0
Little Blue Pin - - - -	0	1½
Shale - - - - -	1	5
Little Blue Pin - - - -	0	1½
Shale - - - - -	0	9
Balls - - - - -	0	1
Shale - - - - -	2	3
Little Blue Vein:—(Anal. LXIX.)		
Little Blue Vein - -	0	3
Shale - - -	2	0
Spotted Pin - - -	0	2
Shale - - -	3	8
Yellow Balls - - -	0	2

	Ft.	in.
Strong Rock	6	9
Shale	0	8
Ironstone	0	2
Shale	1	10
Jenkin Vein	0	2
Shale	0	6
Jenkin Vein	0	2
Shale	2	6
Jenkin Pins:—		
Tobacco Pin	0	1½
Shale	1	2
Smooth Pin	0	0¾
Shale	0	6
Watch Pin	0	0½
Shale	1	1
Double Pin	0	1¼
Shale	0	4
Double Pin	0	0½
Shale	3	0
Lumpy Vein:—(Anal. LXX.)		
Lumpy Vein	0	1½
Shale	0	10
Lumpy Vein	0	2
Shale	2	10
Rough Pin (*garw*)	0	3
Shale	1	8
COAL	1	3
Fire-clay	1	0
Hard Rock	9	3
Ironstone	0	5
Shale	6	0
Ironstone	0	1½
Shale	1	2
Ironstone	0	1
Shale	2	3
Ironstone	0	1
Shale	0	11
Ironstone	0	1½
Shale	2	3
Ironstone	0	1½
Shale	0	9
Ironstone	0	1
Shale	3	3
Ironstone	0	1½
Shale	3	9
Ironstone	0	1½
Shale	1	11
Ironstone (Anal. XIX.)	0	2½
Shale	1	10

	Ft.	in.
Bottom *Rosser Vein*	0	4
Black Shale	3	6
Very hard silicious Rock	3	0
Black Shale	3	0
Ironstone	0	3
Black Shale	0	5
Ironstone	0	3
Black Shale	0	10
Ironstone	0	2
Black Shale	5	5
Ironstone	0	2
Black Shale	4	6
Black silicious Sandstone	1	2
Black Shale	0	9
Upper stratum of Farewell Rock, Light-grey Sandstone	46	9
Black Clay with layers of coal	1	3
Light grey Sandstone	0	9
Shale	1	0
Lower stratum of Farewell Rock	15	9

The above section may be advantageously studied along with the comparative sections of the lower or Ironstone bearing Coal-measures which have been published by the Geological Survey, Sheet No. 8.

By its assistance it is interesting to note, among other points, the considerable area and thickness of strata through which we find the rare minerals Hatchettine and Millerite (sulphide of nickel) occasionally occurring,

The courses of iron ore most remarkable for their presence, are, the Soap Vein (see Blaina); Three-quarter Balls (below the Big Coal) especially farther eastward, at Nant-y-Glo and Blaenafon; and the Spotted Vein.

LVIII.—Dowlais Rosser Vein Mine.

Museum, Practical Geology, Wall-case No. 51.

This ironstone is above the Lower Rosser Vein, and occurs in balls with a very stony appearance and fracture.

This sample was taken as an average.

Soluble in Acids.

	grs.
Silica	0·27
Protoxide of iron	41·03
Alumina	0 23
Protoxide of manganese	0·55
Lime	2·83
Magnesia	3·11

	grs.
Carbonic acid	28·49
Moisture	0·57
Combined water	1·36
Phosphoric acid	0·70
Organic matter	0·07

Insoluble in Acids.

Silica	13·08
Alumina	5·56
Peroxide of iron	0·41
Lime	0·17
Magnesia	0·25
Potash	0·86
	99·54
Metallic iron per cent.	32·18

LXIX., LXX.—Dowlais Welsh Mine.

The following analysis gives the results of a mixture of the several beds of the Little Blue Vein and of the Lumpy Vein, which come next in the series above the Rosser. The Lumpy occurs in balls, or roundish nodules, from two to three inches thick, with many markings of carbonate of lime and iron. The Pin *garw,* or Rough Pin, is of black tint, and with a curious granular structure very seldom seen in ironstone. They are imbedded in shales of a very deep blue colour.

500 grs. (after pulverizing) of each of the four veins composing the Little Blue Vein were intimately mixed together and analysed.

500 grs. (after pulverizing) of each of three veins of Lumpy Vein were intimately mixed together and analysed.

Soluble in Hydrochloric Acid.

	Little Blue Vein.	Lumpy Vein.
Silica (sol.	0·08	0·14
Protoxide of iron	38·77	44·29
Alumina	0·32	0·45
Protoxide of manganese	1·30	1·13
Lime	4·45	3·06
Magnesia	4·25	3·73
Carbonic acid	30·53	32·48
Moisture	0·35	0·42
Combined water	1·08	1·03
Phosphoric acid	046	0·42

Insoluble in Acid.

Silica	13·47	7·77
Alumina	2·96	3·75
Peroxide of iron	0·40	0·41
Lime	0·09	0·12
Magnesia	0·15	0·19
Potash	0·87	0·74
Organic matter	0·29	0·35
Sulphur	0·01	0·03
	99·83	100·51
Metallic iron per cent.	30·43	34·72

Traces of copper found in each in 500 grains of ore.

LXXI.—Dowlais Spotted Vein Mine.

This measure consists of three bands of Ironstone, but that to which the analysis refers is only the lower band, consisting of large balls, or roundish nodules, termed "riders," which sometimes amount to ten or twelve inches in thickness. They are often very cavernous, and exhibit in abundance crystals of quartz, carbonate of iron, and Millerite or sulphide of nickel.

Silica	8·38
Alumina	5·79
Peroxide of iron	76·61
Red oxide of manganese	1·21
Lime	3·13
Magnesia	3·96
Phosphoric acid	0·57
Potash	0·87
Sulphur	0·06
	100·58
Metallic iron per cent. calcined	53·6

LXXII.—Dowlais Gŵr-hyd Mine.

Museum, Practical Geology, Wall-case, No. 51.

This mine is the top vein of the Gwr-hyd. Hard stone, of a brownish hue, and with granular fracture.

Clay	24·44
Protoxide of iron	39·00
Alumina	·89
Oxide of manganese	0·50
Lime	2·75
Magnesia	2·41
Carbonic acid	26·14
Phosphoric acid	1·28
Combined water and organic matter	1·60
Moisture	0·79
	99·80
Metallic iron per cent.	30·33

LXXIII.—Dowlais Black Band.

This ironstone is the bottom vein of the Gŵr-hyd Mine, and the specimen was a very good sample.

Clay	1·21
Organic matter with a little water	11·08
Protoxide of iron	48·66
Lime	1·69
Magnesia	2·61
Carbonic acid	33 09
Phosphoric acid	0·58
Iron pyrites	0·07
Protoxide of manganese	1·21
Moisture	0·25
	100·45
Metallic iron per cent.	37·8

Western Districts.

LXXIV.—Sulphury Mine, Cwm Afon.

(By A. Dick.)

(Nos. 84, 85, and 86 of the Illustrated Catalogue.)

Museum, Practical Geology, Wall-case, No. 52.

This measure occurs between the Finery and the Sulphury seams of Coal, and enjoys a high repute as a good ore. It con-

sists of three courses, averaging about seven inches in thicknes together.

The top vein is a rough granular stone, of blackish grey tint, showing on fracture vertical lines of carbonate of lime and iron.

The middle is very similar, showing also occasional crystals of blackish quartz in the cavities.

The bottom vein is more compact, and breaks with irregularly angular fracture.

Analysis by Method No. III.

Water, hygroscopic and total amount:—	grs.
27 · 17 grs. of ore lost of water at 100° C.	0.08
And gave of water at a red heat	0.02
By the action of hydrochloric acid:—	
12 · 68 grs. of ore gave of—	
Insoluble residue	2 · 85
Manganoso-manganic oxide	0 · 14
Alumina	0 · 18
Sulphate of lime	0 · 44
Pyrophosphate of magnesia	0 · 96
The insoluble residue gave of—	
Silica	1 · 83
Alumina	0 · 82
Peroxide of iron	0 · 05
Pyrophosphate of magnesia	0 · 06
30 · 15 grs. of ore gave of—	
Organic matter	0 · 09
Chloride of potassium	0 · 395
Phosphoric and sulphuric acids, and bisulphide of iron:—	
30 · 84 grs. of ore gave of pyrophosphate of magnesia	0 · 43
24.72 grs. of ore gave of—	
Sulphate of baryta (from sulphates)	trace.
Sulphate of baryta (from bisulphide of iron)	0 · 10
26 · 53 grs. of ore gave of carbonic acid	7 · 47

Iron by standard solution of bichromate of potash:—

Standard: 1 gr. of iron = 8 · 45 cub. cent. of solution.

	Weight of ore.	Cub. cent. of solution.	Per cent. of iron.
I.	15 · 495	40 · 8	31 · 21
II.	11 · 675	30 · 9	31 · 29

Results tabulated.—Ore dried at 100° C.

Protoxide of iron	40·30
Protoxide of manganese	1·03
Alumina	1·43
Lime	1·44
Magnesia	2·77
Carbonic acid	28·23
Phosphoric acid	0·88
Sulphuric acid	trace.
Bisulphide of iron	0·09
Water	0·74
Organic matter	0·29
Insoluble residue	22·48
	99·68

Insoluble Residue.	grs.
Silica	14·43
Alumina	6·47
Peroxide of iron	0·34
Magnesia	0·17
Potash	0·82
	22·23
Iron, total amount	31·63

A trace of copper was detected in 800 grs. of the ore.

YSTALYFERA.

A valuable and interesting series of courses of Iron ore occurs within so moderate a thickness of the coal-measures, that the following (taken in descending order) may be seen in a series of open works, or *patches*, on the hill side, within a few hundred yards of each other :—

Soap Vein—Five courses of two to four inches thick, in twelve feet of ground.

Penny Pieces—A few feet below the last, small grey and often flatly conical stones, intermingled with grey shale, which overlies the

Penturin COAL—Three feet.

White Vein—Four courses of about 16 inches in about 14 feet of ground.

Little Vein—Ten courses in about 18 feet of ground, overlying a coal of two to four feet, commonly called the Four-foot Coal.

LXXV.—WHITE PINS, YSTALYFERA, sometimes called COED-FALDA MINE.

By A. DICK.

(Nos. 100 and 100 *a* of the Illustrated Catalogue.)

Museum, Practical Geology, Wall-case, No. 52.

This measure consists of *balls* and *pins*, or roundish nodules and flat courses; although called white, they are generally of dark grey colour, and have frequent cracks filled with carbonate of lime and iron, which in the iron fracture give a vertical lenticular section.

Analysis by Method No. III.

	grs.
Water, hygroscopic and combined :—	
21·97 grs. of ore lost of water at 100° C.	0·085
And yielded of water at a red heat	0·21
By the action of hydrochloric acid :—	
19·305 grs. of ore gave of—	
Insoluble residue	6·88
Manganoso-manganic oxide	0·15
Alumina	0·17
Sulphate of lime	0·39
Pyrophosphate of magnesia	2·97

The insoluble residue gave of—		grs.
Silica	-	4·81
Alumina	-	1·88
Peroxide of iron	-	0·11
Pyrophosphate of magnesia	-	0·11
45·00 grs. of ore gave of—		
Organic matter	-	0·15
Chloride of potassium	-	0·72
Phosphoric and sulphuric acids, and bisulphide of iron :—		
46·03 grs. of ore gave of pyrophosphate of magnesia	-	0·10
70·00 grs. of ore gave of—		
Sulphate of baryta (from sulphates)	-	trace.
Sulphate of baryta (from bisulphide of iron)	-	0·23
32·25 grs. of ore gave of carbonic acid	-	7·89

Iron by standard solution of bichromate of potash :—

Standard: 1 gr. of iron = 8·45 cub. cent. of solution.

	Weight of ore.	Cub. cent. of solution.	Per cent.
I.	7·85.	15·0	22·61
II.	11·185.	21·6	22·85

Results tabulated.—Ore dried at 100° C.

Protoxide of iron	29·34
Protoxide of manganese	0·73
Alumina	0·96
Lime	0·84
Magnesia	5·63
Carbonic acid	24·56
Phosphoric acid	0·14
Sulphuric acid	trace.
Bisulphide of iron	0·08
Water	1·00
Organic matter	0·33
Insoluble residue	35·73
	99·34

Insoluble Residue.

Silica	24·98
Alumina	9·75
Peroxide of iron	0·53
Magnesia	0·20
Potash	1·00
	36·46

Iron, total amount	23·22

A trace of lead was detected in 910 grs. of ore.

LXXVI.—Catshole Ironstone, Saundersfoot, Pembrokeshire. (By W. Ratcliffe.)

Description.—Clay iron ore; colour, brownish grey; streak, brownish; fracture, flat, uneven; intersected with joints, which are coated with a white powder, and some of which contain crystals of calc-spar and pyrites.

Analysis by Method No. III.

	grs.
Water, hygroscopic and combined :—	
18·693 grs. of ore lost of water at 100° C.	0·070
And gave of water at a red heat	0·223
By the action of hydrochloric acid :—	
15·424 grs. of ore gave of—	
Insoluble residue (ignited)	5·153
Manganoso-manganic oxide	0·201
Silica	0·103
Alumina, sesquioxide of iron, and phosphoric acid	6·023
Pyrophosphate of magnesia	0·404
Sulphate of lime	1·129
The insoluble residue (ignited) gave of—	
Silica	4·027
Alumina, with trace of iron	1·126
Sulphate of lime	0·040
Pyrophosphate of magnesia	0·032
24·440 grs. of ore gave of—	
Organic matter	0·147
Sulphate of potash, from soluble portion	0·052
Sulphate of potash, from insoluble portion	0·142
24·502 grs. of ore gave of—	
Pyrophosphate of magnesia	0·169
Sulphate of baryta (from sulphates)	0·426
Sulphate of baryta (from bisulphide of iron)	0·423
I. 15·782 grs. of ore gave of carbonic acid	3·559
II. 12·509 grs. of ore gave of carbonic acid	2·754

Iron, total amount (soluble) by standard solution of bichromate of potash :—

Standard: 1 gr. of iron = 9·83 cub. cent. of solution.

	Weight of ore.	Cub. cent. of solution.	Per cent. of iron.
I.	9·644	25·00	26·369
II.	10·825	28·00	26·309
Iron as protoxide :—			
I.	23·12	58·50	25·735
II	26·286	66·50	25·736

Results tabulated.

Protoxide of iron	33·088
Sesquioxide of iron	0·637
Oxide of manganese	1·213
Alumina	0·909
Lime	3·014
Magnesia	0·944
Silica	0·668
Potash	0·115
Carbonic acid	22·283
Phosphoric acid	0·441

	Per cent. of iron.
Sulphuric acid - - -	0·597
Bisulphide of iron - - -	0·446
Organic matter - -	0·601
Water, hygroscopic - - -	0·374
Water combined - - -	1·193
Insoluble residue (ignited) - -	33·409
	99·932

Insoluble Residue (ignited).

Silica - - - - -	26·109
Alumina, with trace of iron - -	7·300
Lime - - - -	0·107
Magnesia - - - -	0·074
Potash - - -	0·314
	33·904
Iron, total amount (soluble) -	26·389

No metals precipitable by sulphuretted hydrogen from the hydrochloric acid solution of 150 grains of ore were detected.

LXXVII. Kilvelgy Iron Stone, Saundersfoot, Pembrokeshire.

(By W. Ratcliffe.)

Description.—Clay iron ore ; colour, gray, white on the joints ; streak, light gray ; fracture, conchoidal, rough ; pyrites in some of the joints.

Analysis by Method No. III.

	grs.
Water, hygroscopic and combined :—	
16·178 grs. of ore lost of water at 100° C. - -	0·146
And gave of water at a red heat - - -	0·199
By the action of hydrochloric acid :—	
33·188 grs. of ore gave of—	
Insoluble residue (ignited) - - -	9·056
Manganoso-manganic oxide - -	0·523
Silica - - - -	0.017
Alumina, sesqui-oxide of iron, and phosphoric acid -	13·734
Pyrophosphate of magnesia - - - -	2·766
Sulphate of lime - - - -	1·517
The insoluble residue (ignited) gave of—	
Silica - - - - -	6·237
Alumina, with a trace of iron - - -	2·048
Sulphate of lime - - - -	1·663
Pyrophosphate of magnesia - - -	0·041
32·978 grs. of ore gave of—	
Organic matter - - - -	0·196
Chloroplatinate of potash, from soluble portion -	0·045
Chloroplatinate of potash, from insoluble portion -	0·320

	grs.
37·088 grs. of ore gave of—	
Pyrophosphate of magnesia - - -	0·131
Sulphate of baryta (from sulphates) - -	0·161
Sulphate of baryta (from bisulphide of iron -	0·512
I. 23·147 grs. of ore gave of carbonic acid -	6·069
II. 30·841 grs. of ore gave of carbonic acid - -	8·038

Iron, totsl amount (soluble) by standard solution of bichromate of potash:—

Standard: 1 gr. of iron = 9·83 cub. cent. of solution.

	Weight of ore.	Cub. cent. of solution.	Per cent. of iron.
I.	8·085	23·00	28·930
II.	10·393	30·00	29·366
Iron as protoxide:—			
I.	27·037	70·50	26·527
II.	14·050	37·00	26·789

Results tabulated.

Protoxide of iron - - -	34·274
Sesquioxide of iron - - -	3·366
Oxide of manganese - - -	1·467
Lime - - - - -	1·899
Magnesia - - -	3·003
Silica - - - -	0·051
Potash - - - -	0·027
Carbonic acid - - -	26·141
Sulphuric acid - - -	0·149
Bisulphide of iron - - -	0·287
Phosphoric acid - - -	0·226
Organic matter - - -	0·594
Water, hygroscopic - - -	0·902
Water, combined - - -	1·230
Ignited insoluble residue - -	27·287
	100·903

Insoluble residue (ignited).

Silica - - - -	18·793
Alumina, with trace of iron - -	6·171
Lime - - - -	2·081
Magnesia - - -	0·044
Potash - - - -	0·187
	27·276

Iron, total amount (soluble) - - 29·148

No metals precipitable by sulphuretted hydrogen from the hydrochloric acid solution of 150 grains of ore were detected.

LXXVIII.—Calcareous Hæmatite, Whitchurch (near Cardiff).

(By W. Ratcliffe.)

Description.—Compact; soft; lustre, greasy, to dull; colour, dark red on outside, on the fracture blackish red; streak, bright red; soils the fingers, and makes a red streak on paper; structure, oolitic and sometimes pisolitic.

Analysis by Method No. III.

	grs.
Water, total:—	
I. 41·175 grs. of ore yielded of water at a red heat	·870
II. 50·663 „ „ „	1·072
By the action of hydrochloric acid:—	
16·020 grs. of ore gave of—	
Insoluble residue (ignited)	1·659
Manganoso-manganic oxide	0·194
Silica	0·050
Alumina, with phosphoric acid	0·295
Pyrophosphate of magnesia	0·637
Sulphate of lime	3·296
Pyrophosphate of magnesia, from alumina	0·022
The insoluble residue (ignited) gave of—	
Silica	1·376
Alumina, with a little sesquioxide of iron	0·167
Sulphate of lime	0·233
Pyrophosphate of magnesia	0·121
3·093 grs, of ore gave of—	
Organic matter	0·162
Chlorides of alkalies, from soluble portion	0·183
Chloroplatinate of potash „	0·424
Chlorides of alkalies, from insoluble portion	0·222
Chloroplatinate of potash „ „	0·524
24·522 grs. of ore gave of—	
Pyrophosphate of magnesia	0·390
Sulphate of baryta	0·934
I. 51·683 grs. of ore gave of carbonic acid	2·658
II. 39·654 grs. of ore gave of carbonic acid	2·112

Iron, total amount (soluble) by standard solution of bichromate of potash:—

Standard: 1 gr. of iron = 9·83 cub. cent. of solution.

	Weight of ore.	Cub. cent. of solution.	Per cent. of iron.
I.	7·395	34·50	47·451
II.	11·355	53·00	47·485
Iron as protoxide:—			
I.	18·527	1·50	0·820
II.	18.706	1·75	0·941

Results tabulated.

Sesquioxide of iron	66·554
Protoxide of iron	1·131
Oxide of manganese	1·127
Alumina	1·753
Lime	8·547
Magnesia	1·116
Silica	0·312
Potash	0·190

	grs.
Soda	0·068
Carbonic acid	5·733
Sulphuric acid	1·309
Phosphoric acid	1·017
Organic matter	0·376
Water (total)	2·118
Ignited insoluble residue	10·356
	101·707

Ignited Insoluble Residue.

Silica	8·589
Alumina (with a little iron)	1·042
Lime	0·850
Magnesia	0·272
Potash	0·235
Soda	0·076
	11·064

Iron, total amount (soluble)	47·468

No metal precipitable by sulphuretted hydrogen from the hydrochloric acid solution of 300 grains of ore was detected.

LXXIX.—Hæmatite, Llantrissant, Glamorganshire.

(By W. Ratcliffe.)

Description.—Compact red hæmatite; easily scratched by a file; lustre, earthy; colour, deep red-yellow; streak, brown-red; fracture, uneven, showing numerous cavities lined with crystals of quartz: the ore contains minute particles of quartz visibly diffused through it. Some specimens, selected from large solid masses of the ore, are scarcely scratched by a file; colour, bright purple-blue: particles of quartz are diffused through these, and are only plainly visible by the aid of the microscope. The sample analysed was composed of a mixture of these varieties.

Analysis by Method No. II.

Results tabulated.

Sesquioxide of iron	70·572
Oxide of manganese	0·522
Silica	18·362
Alumina	1·572
Lime	3·562
Magnesia	1·311

	grs.
Potash - - - - -	0·317
Sulphuric acid - - - -	0·451
Phosphoric acid - - - -	0·132
Carbonic acid - - -	1·716
Water (total) - - -	0·660
	99·177
Iron, total amount - - -	48·934

A distinct trace of cobalt was detected in 300 grains of the ore.

On the Fossils of the South Welsh Coal Field.

Part I.—Ironstones of the "North Crop." (By J. W. Salter, A.L.S.)

The following is a trifling contribution only to the palæontology of our coal fields, a subject greatly requiring illustration. Except Mr. Prestwich's paper on the Coalbrooke Dale strata,* Dr. Hibbert's memoir, Mr. Binney's descriptions, and a few others, little has been really done towards working out the distribution of the coal fossils.

We know less, perhaps, of the succession of the coal strata than of any others in the United Kingdom, though they are the most important of all. Nearly every bed of the Oolites, and even of the older Palæozoic rocks, has had its place determined, and its organic contents are more or less known. But our hundred coal and ironstone beds have hitherto been treated as a whole, (they form a mass 4,000 to 12,000 feet in thickness,) and the succession, mineral aspect, &c. of these beds have yet been traced only for each separate locality; the data, in many cases supplied by practical miners, being registered on our maps.

The comparison, therefore, even of neighbouring coal fields, is not yet made, yet this should have a high scientific value, if not a practical use. A knowledge of the exact position of the beds below him, upon commencing his shaft, must always be a boon to the miner. And when the ground is faulted, there should be other data on which he may safely rely, besides the aspect of the measures brought up by the borer. In every other thick formation it has been found possible to ascertain the horizon with tolerable certainty by the aid of fossils. It is hoped, therefore, by the help of such coal proprietors, ironmasters,

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* Geol. Trans., 2d series, vol. 5, f. 41–3.

and mining engineers as will take the pains to collect accurately,* that we may be able to offer the public useful information.

For some time the Geological Survey has been seeking to obtain data of this kind by registering such facts as occurred in the course of the field work. But collections of coal fossils can only be really made by the managers of the collieries, since the moment the specimens become mixed on the mine-tip, their value for determination of the beds is gone. The small collections on which the following lists are based, were the fruit of careful work; the contents of each bed being sedulously kept from mixture with any other.

Mr. W. Adams of Ebbw Vale, and Dr. G. P. Bevan of Beaufort, are responsible for the exact localities. The latter has published a valuable list of plants from the Elled Coal†, and some remarks on the Rosser Veins below the "Farewell Rock." To both of these gentlemen we are much indebted, and not less so to our friend Ebenezer Rogers, Esq., late president of the South Wales Institute of Engineers, for zealous assistance rendered in the very kindest way.

The contents of the "Ironstone" bands are alone given here. The coals will, it is hoped, be taken up another time. The lists are drawn up from two collections only, and to save space the letter (A.) after the locality will stand for Mr. Adams' collection, and (B.) for that of Dr. Bevan.

In the plates the more characteristic specimens only are figured. The species are not all confined to the particular bands indicated, and the subjoined tables will show the distribution so far as yet ascertained.

A few explanatory notes on the species of each band are added, and the beds are taken in ascending order.

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* Detailed measures and specimens from well ascertained sections will be thankfully received by the Paleontologist, at the Museum of Practical Geology.

† Geologist, vol. 1, p. 128.

I. Rosser Veins.

Under the Farewell Rock*; (wholly marine.)

——	Plate in this Memoir.	Localities in South Wales.	Other Localities.
Spirifer Urii., Flem.	Pl. 1, f. 24.	Glan Rhymney (A.)	Carbs. Limest., Scotland, N. Devon in Marwood beds (Uppermost Devonian).
—— glaber, Sow. (Min. Conchology, t. 269).	- - -	Glan Rhymney (B.)	Carbs. Limestone, everywhere.
—— bisulcatus, Sow.	Pl. 1, f. 26	Glan Rhymney (B.)	Do. do.
Orthis Michelini, Lev.	Pl. 1, f. 23	Glan Rhymney (A.B.)	Do. do.
—— resupinata, Sow	Pl. 1, f. 25	Glan Rhymney (A.B.)	Do. do.
Streptorhynchus crenistria (Orthis crenistria, Phillips).	Pl. 1, f. 27	Beaufort (B.)	Do. do.
Chonetes Hardrensis, Ph.	Pl. 1, f. 22	Glan Rhymney (A.B.)	Carbs. Shales, everywhere.
Productus semireticulatus, Martin. (P. antiquatus and P. Martini, Sowerby.)	Pl. 1, f. 32, 33.	Beaufort (B.) Glan Rhymney (A.) Cwm Bryn-ddu (A.)	Carbs. Limestone from N. Pole to Australia; Andes; India.
—— hemispherica, Sow.) (P. Cora, D'Orb.)	Pl. 1, f. 31	Beaufort (B.)	Do. do.
Disoina nitida, Phill. (G. Yorksh. vol. 2, pl. 11, f. 10–13.)	- - -	Beaufort Glan Rhymney (B.)	Carbs. Limestone, Yorkshire. *Pennystone and Blackstone*, Coalbrooke Dale.
Lingula mytiloides, Sow. (Min. Conch. t. 19.)	- - -	Valley N. of Dowlais big pond (A.B.)	*Pennystone*, Coalbrooke Dale, Oldbury and Portway, Dudley. Carbs. Limestone, Durham.
Aviculopecten gentilis, Sow. (G. Trans., pl. 39, f. 19.)	- - -	Beaufort (B.) Glan Rhymney (B.)	*Pennystone*, Coalbrooke Dale.
—— scalaris, Sow. (G. Trans., pl. 39, f. 16.)	- - -	Cwm Bryn-ddu. (A.)	*Pennystone*, Coalbrooke Dale.
Myalina triangularis, Sow. (G. Trans., pl. 39, f. 16.)	- - -	Beaufort (B.)	*Crawstone*, Coalbrooke Dale
Arca (striate sp.)	- - -	Rhymney (B.)	
Myacites (sp.)	- - -	Rhymney (B.)	
Schizodus sulcatus (G. Trans., pl. 39, f. 1.)	- - -	Cwm Bryn-ddu (B.)	*Pennystone*, Coalbrooke Dale.
—— carbonarius (G. Trans., pl. 39, f. 2.)	- - -	Cwm Bryn ddu (B.)	Do. do.
Ctenodonta undulata, Ph. (G. Yorksh., pl. 5, f. 16.)	- - -	Glan Rhymney (B.)	Carbs. Limestone, Yorkshire.
—— gibbosa, Flem. (G. Yorksh., pl. 5, f. 15.)	- - -	Glan Rhymney (B.)	Carbs. Limestone, Scotland; England; Ireland.
—— æqualis, Sow. (G. Trans., pl. 39, f. 3.)	- - -	Cwm Bryn-ddu (A.) Beaufort (B.)	*Pennystone*, Coalbrooke Dale.
Edmondia unioniformis, Ph.	Pl. 1, f. 29	Glan Rhymney (B.) Beaufort (B.)	Carbs. Limestone, everywhere.
Myacites sulcata, Flem.	Pl. 1, f. 28	Glan Rhymney (B.) Beaufort (B.)	Carbs. Limestone, Northumberland, Coalbrooke Dale.
Pleurotomaria limbata, Ph. (G. Yorksh., pl. 15, f. 18.)	- - -	Glan Rhymney (B.)	Carbs. Limestone, Yorkshire.
Macrocheilus (minute)	- - -	Cwm Bryn-ddu (B.)	
Litorina? obscura, Sow. (G. Trans., pl. 39, f. 23.)	- - -	Beaufort (B.)	Coalbrooke Dale.
Conularia quadrisulcata, Sow.	Pl. 1, f. 34	Glan Rhymney (B.)	Carbs. Limestone, Glasgow. *Pennystone & Ch. Pennystone*, Coalbrooke Dale.
Bellerophon apertus, Sow. (Min. conchol., t. 469.)	- - -	Cwm Bryn-ddu (A.)	Carbs. Limestone, Yorkshire.
—— decussatus, Flem. (Portl. G. Rep., pl. 29, f. 6.)	- - -	Beaufort (B.)	Carbs. Limestone, Ireland.
—— hiulcus, Sow. (G. Tr.. pl. 40, f. 10, not of Min. Conchology.)	- - -	Beaufort (B.)	*Pennystone*, Coalbrooke-dale.
Discites falcatus, Sow.	Pl. 1, f. 37	Glan Rhymney (A.B.)	Do. do.
Nautilus concavus, Sow. (G. Tr., pl. 40, f. 6.)	- - -	Beaufort (B.)	Do. do.
Goniatites Listeri, Sow.	Pl. 1, f. 35, 36.	Glan Rhymney (A.B.)	Coal Measures, Yorkshire.
Orthoceras	- - -	Glan Rhymney (B.)	
Encrinite stems	- - -	Beaufort (B.)	
Megalichthys Hibberti, Ag., and one or two other fish fragments.	Pl. 1, f. 16	Cwm Bryn-ddu (A.) Beaufort (B.)	*Pennystone* to *Ch. Pennystone*, and all intervening beds, Coalbrooke Dale.

* Not the Millstone Grit, usually called "Farewell Rock;" these thick sandstones lie above it.

These now well-known beds, occuring with thin seams of coal, rest, according to Mr. W. Smyth, on a "ganister" floor.* They are all unquestionably of marine origin, since they contain genera which are never known to occur in fresh-water deposits. Indeed the *Spirifer bisulcatus*, *Orthis Michelini* and *O. resupinata*; and more especially the Producti—*P. semireticulatus* and *P. Cora*, are among our commonest mountain limestone fossils. The same may be said of *Edmondia unioniformis*, *Bellerophon apertus*, *Megalichthys Hibberti*, and some others.

The species known in the Coalbrooke-Dale measures have their localities marked in italics in our list. It will be seen how close a relation the Rosser Veins have with the great lower bed of ironstone in Coalbrooke Dale. These penny-stone fossils are marine species, yet are found to be chiefly distinct from those of the mountain limestone. This result was perhaps hardly to be expected, yet the fact that they are distinct indicates that we shall find great differences between the various beds of the Coal-measures themselves, when once they have been studied accurately.

Anthracosia acuta occurs, as we see, along with these marine forms. There is a similar association in the lower beds of the Lancashire Coal Series. There seems to be little reason for believing that the genus is of freshwater origin. This point will be noticed by-and-bye.

II. Bottom Vein. (Marine.)

The black hard shales connected with the "Bottom Vein" ironstone have yielded nothing but ganoid and placoid fish. The list is as follows:—

——	Plate.	Localities; Ebbw Vale.	Other Localities.
Rhizodus granulatus, Ag., teeth,—large and small.	Pl. 1, f. 1, 2, (3?)	Gantre pits, Ebbw Vale (A.B.)	Flint; Madeley; *Bassy Coal*, Staffordsh.; Coppull, Lancashire; Ashby.
—— —— scales, smaller than those of *R. Hibberti*, probably belonging to the same species as fig. 1-3.	Pl. 1, f. 4-6	Gantre pits (A.B.) - Beaufort (B.) Sirhowy (B.)	*Yard Coal*, Cheadle (W. Smyth); Madeley, Coalbrooke Dale; Queen's Cross, Dudley; Flint.
—— *granulatus*, elongated plates of the throat, striated outside.	Pl. 1, f. 7-8	Gantre pits (A.B.) -	Flint, Mold, Llangollen; Lancashire; Ashby.
—— ditto, fin rays of ditto,	Pl. 1, f. 9	Gantre pits (A.B.) -	Flint, Llangollen.
—— ? bones of head -	Pl. 1, f. 15	Gantre (A.)	
Pleuracanthus gibbosus, teeth (*Diplodus*, Ag.)	Pl. 1, f. 10	Gantre pits (A.) -	Flint, Mold; Staffordshire Lancashire.
Byssacanthus ? - -	Pl. 1, f. 21	Gantre (B.) - -	
Palæoniscus, sp. - -	Pl. 1, f. 11-14.	Gantre (A.) Sirhowy (B) Beaufort (B.)	Arley Mine, at Saffog Colliery, Lancashire.
Amblypterus (fluted throat-plates, Agass., vol. 2, pl. 3.)	- -	Gantre (A.) - -	*Flint Coal bass*; *Top Coal* and higher beds in Coalbrooke Dale; Flint; Dudley; Lancashire.
Megalichthys Hibberti -	Pl. 1, f. 16	Gantre (A.) - - Dowlais (B.)	
Helodus simplex, Ag. -	Pl. 1, f. 17	Gantre (A.) - -	Staffordshire; Coalbrooke Dale.
Pœcilodus angustus, Ag. -	Pl. 1, f. 18-19.	Gantre (B.) - -	Carluke, Lanarksh.; Talacre, Flint; *Top Coal*, Madeley.
P. ——, sp. - -	Pl. 1, f. 20	Gantre (B.) - -	Talacre, Flint.

* Mr. Binney has described some of the Lancashire beds as having such a floor, and it is no uncommon thing for the Scotch coals, which are so decidedly entangled among marine beds of limestone and shale, to rest upon sandstones instead of fire clays.

As mentioned in the list of localities, there is a very similar fish-bed in black bass at Saffog Colliery near Wigan. Mr. Edward Hull *, who found the specimens, tells me it occurs in the roof of the "Arley Mine," the lowest of the coals above the "Gannister" series. It is possible, therefore, that this may be on the same horizon.

It so happens, that some of the fish here enumerated are yet undescribed. They are, however, so common and characteristic, that they ought to be figured. Others have received names but no descriptions. The *Rhizodus* scales and teeth (perhaps even the bones of the head, Fig. 15) belong, in all probability, to the same species. It has been called *Holoptychius granulatus* by Agassiz.

Rhizodus granulatus, Ag. sp., Pl. 1, f. 4—6.

Holoptychius granulatus, Poiss. Foss., vol. 2, p. 180.

This *Rhizodus* has oval, not circular, scales, which vary considerably in outline and proportionate width and length. The extreme size is $\frac{3}{4}$ by $\frac{1}{2}$ an inch. All the scales have a triangular exposed surface, characterized by granules irregularly scattered on it. This granulated area reaches to the hinder or pointed edge. As the specimens are all casts of the scales, some have on the surface raised granules, while others which are casts of the opposite surface, show corresponding pits. It is probable the outer side of the scale over this area was tubercular, and the inner punctate. The great *R. Hibberti* has more rounded scales, but shows a like granular and striated surface. *R. Portlockii* has somewhat similar characters, but not so conspicuously shown.

Teeth of ditto, Pl. 1., ff. 1–3.

In all probability these teeth belong to the same species as the scales above noted. They are closely striated at the base and for a long way up, while those of *R. Hibberti* and *R. Portlockii* are ribbed at the base and smooth above, besides being five times the size of these. Fig. 3 is doubtfully identified; it is elegantly striated, and partly fluted also at the base.

The smaller tooth here figured appears to be only one of the intermediate or smaller teeth of the same species, and such always occur with the large ones.

Throat Plates, (Hyal Plates) Pl. 1., ff. 7, 8.; and *Fin-rays*, f. 9.

The beautiful ornament of the surface distinguishes these throat-scales or plates. They are often an inch long, and the largest I have seen is four lines broad.

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* See his memoir on the Geology of Wigan, Mem. Geol. Survey, 1860. Explan. of Map 89, S.W.

The plates are ovato-lanceolate or ovate-oblong, obliquely truncate at the two ends, and pointed; convex along the whole length. The surface is closely ornamented with vermicular raised lines, which are curved and transverse over one half, but at about the middle of the plate bent on themselves, more and more, till they run parallel to the lateral border at the opposite end of the plate. These vermicular ribs are short, interrupted, sinuous, interlocking with each other, and rather closely placed, as shown in our magnified figure, but leaving sharp furrows between them. Underneath, the plate shows a strong ridge running from end to end.

A very similar sculpture occurs on the head plates of *Palæoniscus*. See Egerton, in Quart. Geol. Journal, vol. 6, Pl. 1.

Pleuracanthus (*Xenacanthus*) *gibbosus*, Ag., Pl. 1. f. 9.

It has been shown by Sir Philip Egerton, that the spines called *Xenacanthus* and *Pleuracanthus*, as well as the double shark-like teeth (*Diplodus*),—all common in the coal,—are teeth and spines of the same fish. There is a good specimen, collected by Mr. R. Gibbs, in our museum, which shows the whole number of teeth in the gape, and their number is not less than 60,—probably more.

In ordinary shark teeth, the central cusp is the long one, and the lateral spines are small: in *Diplodus* the reverse takes place,—the outer cusps being extravagantly developed, and the central one quite lost, or reduced to a tubercle.

Byssacanthus? Pl. 1. f. 21.

The spine (fig. 21) is imperfect, but it is figured to draw further attention. *Pleuracanthus* is the common genus in the Coal. *Byssacanthus*, to which Sir P. Egerton is inclined to refer this spine, is a Devonian genus.

Megalichthys Hibberti, Ag. Pl. 1, f. 16.

The large punctate rhomboidal scales enable one to recognize this common fish from the merest fragments.

There are specimens of the entire fish in the Mus. Pract. Geology. A fine head, presented by Mr. Blackwell, shows the rounded muzzle, minute teeth, and large punctate throat plates. All are beautifully preserved.

The species has a remarkably wide distribution in time, occurring in Scotland in the beds *below* the mountain limestone, and ranging in England as high as the topmost layers of the coal strata; nor is it rare throughout all this range.

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* Ann. and Mag. Nat. Hist. vol. 20, p. 423.

Palæoniscus, sp., Pl. 1, ff. 11–14.

Scales oblong, rhomboidal, with five or six branched and sinuous furrows, running obliquely from the longer angles, and inosculating. They cover the whole surface, which is not the case in *P. Robisoni* or *P. striolatus*; while in *P. ornatissimus* which is striated throughout, their direction is rather across than along the scales; and they are far more numerous. Our figures are much magnified.

It is certain the scales afford good characters in this genus. The species occurs at Saffog and Freeman Collieries in Lancashire, in the "fish bed"* which has so many species in common with ours, that we can hardly doubt the "Bottom Coal" being on the same geological horizon.

Amblypterus.

Scales of this genus are not common anywhere, but occur in some of the Scotch localities; they have not yet been detected here, but the lobed throat-plates, which Agassiz has figured for this genus in his vol. 2, pl. 3, are found at Gantre.

Pleurodus affinis, Ag., Pl. 1, f. 18, 19.

(Agassiz, Poiss. Foss., Pl. 3, p. 174.)

Of this there is yet no description. It is common in our coal-fields. With it occurs a *Pœcilodus* which seems different from all those described by Portlock or McCoy; it resembles the *P. obliquus* of the Mountain Limestone, but the ridges are more regular, and the form shorter and less constricted.

Pœcilodus (?), sp., Pl. 1, fig. 20.

This, with its strong median ridge, is very like the form of the *Pleurodus*, which accompanies it. But there are no ridges beside the central one. The ends are truncate, and one is subdentate.

Helodus simplex, Agass., Pl. 1, fig. 17.

Agassiz has figured a very imperfect tooth under this name, showing a simply conical mass, with the usual punctate structure.

N.B.—The lines near the specimens express the actual size.

We are indebted to Sir P. Egerton for accurately naming most of the fragments figured in our plate. It is much to be regretted that so many of Agassiz's species are yet undescribed and unfigured.

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* Discovered by Edw. Hull, Esq. to hold a definite place in this coalfield.

II.* Blue Vein, or Big Vein.

(Marine.)

We have received from Dr. Bevan the following species :—

——	Plate.	Localities Ebbw Vale.	Other Localities.
Myalina carinata, Sow. -	Pl. 2, f. 15	Ebbw vale (W. Smyth)	
Anthracosia acuta - -	Pl. 2, f. 21	Ebbw vale (B.)	
—— (ovalis or centralis) -		Rhase, Beaufort (B.)	
Spirorbis carbonarius -	Pl. 2, f. 23	Sirhowy (B.)	

III. Red Vein.

(Brackish Water or Marine.)

——	Plate.	Localities in South Wales.	Other Localities.
Anthracosia acuta, Sow. -	Pl. 2, f. 20	Gantre (A,) - -	*Dogtooth* Ironstone, Derbyshire.
—— ovalis, Martin -	Pl. 2, f. 22	Ebbw vale (B.) -	Bradford.
Modiola, small convex species	- -	Ebbw vale (B.)	
Edmondia?, a shell like a Cyprina, our specimen shows the inner cast only.	- -	Beaufort (B.),	

The first two of these shells will be readily recognized, and of all the species of *Anthracosia*, perhaps these two are the most common and widely spread in England. The *A. ovalis* is found also in Belgium.

Anthracosia.

Originally considered as species of *Unio* by Sowerby, these Coal shells have been a good deal tossed about; Agassiz formed a genus *Cardinia* for the species of supposed Unio found in the Lias and Coal; and Mr. Stutchbury called them *Pachyodon*. But then it was found that the Coal species did not belong to the same genus as those of the Lias. Professor King, of Galway, having obtained very good interiors, showed some reasons for believing they belonged to the true Unio family, but as they had no supplementary muscular scar, and no teeth in the thick hinge, he named them *Anthracosia*,—an excellent name, whatever be their scientific place.

There is much doubt, after all, whether they belong to the *Unionidæ*.

Anthracosia was, I believe, a burrowing shell. Among beds where these fossils were the only bivalves, I have seen bivalve-burrows answering to them in size.* It had certainly a thick and wrinkled epidermis, as the *Myadæ* have, and no eroded beaks,

* See also Binney, in Mem. Lit. and Phil. Soc. of Manchester, vol. 10, Pl. 2.

as is common in Unio. But the pallial line was simple, and the valves close. In the majority of the Mya-like shells the reverse is the case. Yet *Pandora* and *Lyonsia* have the valves close, *Ceromya* has the "pallial line scarcely sinuated" (Woodw.), and in *Lyonsia* it is but a slight sinus.

If any one will ascertain the position of the *Anthracosia* in the beds, and find whether they are ever *vertical*, as if inhabiting the mud, he may help to settle the question; for the *Unionidæ*, as a rule, do not burrow†. Woodward places *Anthracosia*, with some doubt, among the *Cyprinidæ*. Its thick epidermis favours this view, but I believe it nearer to the genus *Anthracomya* (described in p. 65). It certainly had an internal ligament; this is shown in a fine specimen in the Geological Society's Museum.

Meantime, there is yet more doubt if they can be freshwater forms, associated as they always are with *Modiola* and other true sea animals. It is even, as cited in the "Rosser Veins," p. 57, found in company with *Goniatites*, and a host of other marine shells. Mr. Binney, and lately Mr. E. Hull, have shown the same thing for Lancashire.

IV. Spotted Vein.

(Probably Marine.)

—	Plate.	Localities in South Wales.	Other Localities.
Spirorbis carbonarius, Murch.	Pl. 2, f. 23	Beaufort (B.) - -	Lancashire, Yorkshire, &c., all through the coal.
Track of a crustacean (Limulus?), 6 feet under the "spotted vein."	Pl. 2, f. 24	Ebbw Vale (A.)	

The small spiral annelide, which is so common in every coal-field in Britain, is known in many other countries, and is one of the most frequent fossils in Nova Scotia. Sir R. I. Murchison described it under the name of *Microconchus* in the Silurian System, and Mr. Binney (Manchester Geol. Soc., 10, t. 2. f. 3) first showed its great prevalence in the coal.

At present all Spirorbes are *marine*, or, at the least, estuary shells, and their frequent attachment to stems of *Sigillaria*, and other coal plants, is a strong indication of the *habitat of the plants themselves.**

The track may have been made by a *Limulus*, or some crustacean unknown. It is evident that several pairs of feet were employed, and the slight impressions along the centre of the track indicate an animal which did not trail its caudal appendages on the ground. *Limulus* habitually keeps its styliform tail or telson raised in the water, with a slight rotatory motion, (C. Gould).

* Mr. Binney has argued, and I think with undeniable force, that the whole weight of evidence is in favour of the coal trees having grown in shallow sea water. (Trans., Manchester Geol. Soc., vol. 8.)

† *Mycetopus*, however, does burrow, like a Solen (Woodward *in literis*).

V. Old Coal (Black Band).

(Marine ?)

—	Plate.	Localities in South Wales.	Other Localities.
Anthracosia acuta, Sow. -	Pl. 2, f. 21	Gantre (A.) - -	Lancashire, Yorkshire, Warwickshire, &c., all through the coal.
——— ovalis, Mart. -	Pl. 2, f. 23	Do. (A.) - -	Do. do.
Rhizodus granulatus, Ag. -	Pl. 1. f. 5	Do. (B.) - -	Do. do.

VI. Mine over "Engine Coal."

(Marine.)

—	Plate.	Localities in South Wales.	Other Localities.
Spirifer bisulcatus, Sow. -	Pl. 2. f. 19.	Clydach (A.) - -	Carb. Limestone frequent; *Pennystone*, Coalbrooke Dale.
Productus scabriculus, Sow. -	Pl. 2. f. 18.	Pontypool (A.) - -	*White Ironstone*, Rosley Staffordshire; Millstone Grit, Bristol; *Pennystone* and *Ch. Pennystone*, Coalbrooke Dale.
Neuropteris Loshii, Brong. - t. 73.	- - -	Sirhowy (B.) - -	Newcastle: Dudley, Staffordshire; Saxony.

This would appear to be the uppermost limit reached by the common mountain limestone shell, *Spirifer bisulcatus ;* but the *Productus* rises in Coalbrooke Dale as far as to the top ironstone, viz. the "Chance Penneystone." *P. scabriculus* has a wide range, and certainly occurs in the Millstone Grit and Mountain Limestone, but the large shell with irregular spines, and rugged wrinkled sides, found also in the Carbs. Limestone, and which sometimes goes under the same name, is a distinct species,—the *P. pustulosus* of Phillips.

VII. Darran Pins.

(Marine or Brackish.)

—	Plate.	Localities in South Wales.	Other Localities.
Anthracomya senex, n. sp. -	Pl. 2. f. 12	Ebbw Vale (A.)	
——— modiolaris, Sow. (Unio. G. Trans.)	Pl. 2. f. 13	Sychffos (A.) - -	*Crawstone*, Coalbrooke Dale.
Myalina modiolaris - - (Avicula, G. Tr., pl. 39, f. 18)	Pl. 2. f. 14	Ebbw Vale (B.) -	*White Flats*, Coalbrooke Dale.
——— quadrata, Sow. - (Avicula, G. Tr., pl. 39, f. 17)	Pl. 2. f. 16	Sychffos (A.) - -	*White Flats* and *Pennystone*, Coalbrooke Dale, Oldbury, Dudley.
——— carinata, Sow. - (Modiola, G. Tr., pl. 39, f. 15)	Pl. 2. f. 15	Sirhowy (B.) - - Cwm-ammon (M.P.G.)	*Crawstone*, Coalbrooke Dale, Queen's Cross, Dudley.
Anthracosia aquilina, Sow. -	Pl. 2. f. 17	Sychffos (A.) - -	*White* and *Blue Flats* Coalbrooke Dale.
——— ovalis ? (or centralis, G.Trans., pl. 39, f. 13)	- - -	Sirhowy (B.) - - Cwm-ammon (M.P.G.)	Yorkshire; Belgium.
——— thick squarish, sp.	- - -	Ebbw Vale (M. P. G.)	
——— lateralis, Brown (var. of A. acuta ?)	- - -	Ebbw Vale (Smyth).	

Here we have a group of bivalves very common in the coal-beds, and which have the general aspect of mussel-shells, and Modiola, while they differ in several particulars from these bivalves. Of the first (a new genus) more will be said in describing the "Three-quarter Vein." Of the three following, however, the marine nature can hardly be disputed. They have been referred to Avicula, but are probably Myalina, that genus being common in the mountain limestone; thousands of these shells occur in banks and layers in the Lower Carboniferous beds of Scotland, among numerous marine genera, *Encrinites, Echini*, &c. &c. They are found also with *Natica*, a sea shell, in the Devonian rocks, where they make their first appearance, and are not uncommon also in the Permian system.

In the Coalbrooke Dale coalfield it is in the "white flats" that the *Myalinæ* occur, and rarely in the "Pennystone." The *Anthracosia aquilina* is a very common species in Coalbrooke Dale.

VIII. Mine (Will Shone, or Pin Will Shone) over Bydyllog, or "Ras Las" Coal.

(Marine.)

—	Plate.	Localities in South Wales.	Other Localities.
Athyris planosulcata, Sow. -	Pl. 2, f. 11	Beaufort Ch. (B.) -	Carboniferous Limestone, Derbyshire; Yorkshire.

Dr. Bevan has specially quoted the fossil from this bed, and feels no doubt of its occurrence there. It is given, therefore, on the authority of his specimen. The species has not yet been found in the Rosser Veins, or lower marine beds of this section. It is a rather common mountain limestone shell.

IX. Mine over "Three-quarter Coal."

(Marine.)

—	Plate.	Localities in South Wales.	Other Localities.
Anthracomya (new genus) pumila, n. sp. -	Pl. 2, f. 10	No. 6 Pit, Victoria (A.)	
———, subcentralis, n. sp.	Pl. 2, f. 9	Do. do.	

Anthracomya, new genus. (Myadæ.)

Nearly equivalve, the right valve rather larger; valves close, oblong, widest posteriorly, where there is a blunt siphonal ridge; rounded anteriorly, a slight byssal furrow (as in *Modiola*) running from the beaks, which are small, anterior, and but little prominent, with an obscure lunette; posterior hinge line with a narrow interior ridge; ligament external. Epidermis strongly wrinkled.

There have always been a few sheils which, in lists of Coal fossils, have oscillated between *Avicula* and *Modiola*, and even *Unio*; for these the discovery of a common character in the epidermis at length enables me to propose a generic term.* The following species belong to it; but the type I consider to be the first species mentioned.

Species of *Anthracomya*.

	Plate.	
A. Adamsii, n. sp.	Pl. 2, f. 7.	Type species in form and surface
A. pumila, n. sp.	Pl. 2, f. 10.	Characteristic epidermis.
A. subcentralis, n. sp.	Pl. 2, f. 9.	
A. senex, n. sp.	Pl. 2, f. 12.	A characteristio species, in form and surface.
A. (Unio) *modiolaris*, Sow.	Pl. 2, f. 13.	
A. (Unio) *dolabrata*, Sow. (G. Trans., vol. 5, pl. 39, f. 9)		Characteristic in form, but shows only slightly wrinkled epidermis.
A. ? ——— sp. (Avicula modiolaris, Sow.)	Pl. 2, f. 14.	Aberrant form.

I will take the type species first. It belongs, however, to the "Soap Vein," not yet described.

Anthracomya Adamsii, n sp., Pl. 2, f. 7.

Obliquely ovate, compressed, with the ventral margin much curved; narrower at the short rounded anterior end, broadest at about one fourth from the posterior subtruncate margin. The valves are very slightly unequal,—the right most convex. The posterior convex ridge very obtuse, the (byssal) furrow broad and shallow, and with no perceptible marginal notch, lunette short and narrow. Epidermis moderately wrinkled in front, much so posteriorly. Length nearly two inches, height one inch, depth ot valves united seven lines.

A very much compressed species, with the look of a smooth Myacites; to which in fact it is allied. *A. modiolaris* is more convex, more pointed in front, and wider posteriorly. *A. dolabrata* is still more convex, and has an almost obsolete anterior side.

Locality. "Soap Vein," Pen-y-cae. (See p. 69, M'Adam's cabinet.)

A. pumila, n. sp., Pl. 2, f. 10.

Transversely oblong, gently convex, twice as wide as long, with depressed beaks close to the anterior end; the hinge line scarcely at all curved, parallel to the ventral margin which is qnite straight; a short and rather pointed anterior side, in full grown specimens not one fifth the length of the posterior side, which is obliquely truncate and blunt pointed, with a siphonal

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* I am not sure that the so-called *Myalina*? *quadrata* and *M.*? *carinata* may not belong to this genus, which is an exceedingly common one under one form or another in the Coal. Prof. W. King has evidently had one of these groups in view, as appears by a reference made to it in his paper on *Anthracosia*. (Ann. & Mag. Nat. Hist., Jan. 1846, vol. 7.) I hope he will publish on the so-called *Myalinæ* of the Coal. They have not the thick hinge plate of that genus, but I cannot yet find that their epidermis will agree with that of the group here described.

ridge. No distinct byssal sinus. Surface finely striate concentrically, and the epidermis areolated but tolerably smooth, except on the anterior and pedal margins, where it is roughly folded.

A pretty little shell, evidently distinct from *A. Adamsii*, but young specimens are not so easy to separate from *A. subcentralis.* When full grown the transverse form easily distinguishes it.

Locality. No. 6 pit. Victoria. (Mr. Adam's cabinet.)

A. subcentralis, n. sp., Pl. 2, f. 9.

Transversely oblong (width once and a half the length), subconvex, both ends rounded, the anterior prominent, as broad as the posterior which is traversed by a blunt ridge; dorsal and ventral margins nearly parallel, the latter sinuate beneath the broad (byssal) furrow; beaks at one third from the anterior end, rather prominent for the genus. Surface scarcely striated by lines of growth, but covered with a strong rugose epidermis.

The more convex form and subcentral beak distinguishes this from *A. pumila*; from the larger species, *A. Adamsii*, the straight ventral margin and produced anterior side sufficiently separate it.

Locality. No. 6 pit. Victoria. (Mr. Adam's cabinet.)

One more species, referred to in p. 66, completes our list at present; viz.—

A. senex, Pl. 2, f. 12.

One inch wide, very unequal-sided (modioliform), the beaks close to the anterior end, which is divided by a well marked byssal furrow and notch from the posterior side,—the latter is convex along the blunt siphonal ridge; anterior side very short, its edge falling vertically under the rather prominent beak. The posterior side (or slope) is expanded and very convex; the hinge line raised; the ventral margin sinuate and concave.

The general appearance is that of an ordinary convex Modiola; but the epidermis, deeply wrinkled V-fashion over the posterior slope, shows its true affinity.

Locality. "Darran Pins," Ebbw Vale, Sychffos. See last page. We cannot get at the interior, but there is not much doubt there is a pallial sinus; and there were probably long siphonal tubes covered by a thick epidermis, the animal burrowing in the mud as most of the Myadæ do.

X. Mine under Big Vein Coal.

(Marine ?)

	Locality in S. Wales.
Anthracosia centralis ? (an oval species, smaller than S. ovalis	Cwm Clydach A.)

This is the same species that occurs in the "Darran Pins." It is not uncommon.

XI. Ell Balls, above Elled Coal.
(Terrestrial Surface ?)

—	Plate.	Localities in South Wales.	Other Localities.
Asterophyllites grandis Lindl. (Foss., Fl., t. 17, t. 19, f. 2.)	- - -	Llwyd coed patch (A.)	Newcastle.
Lepidodendron selaginoides, (Sternb, t. 16, f. 3, t. 17, f. 1.)	- -	Beaufort (A.B.) - -	*Ballstone*, Coalbrooke Dale; Lancashire; Pembrokeshire.
Lepidodendron Sternbergii, Brong. (Lindl. Foss. Fl., t. 4, 112, 203.)	- - -	Do. do. - -	*Ballstone*, Coalbrooke Dale; Newcastle; Lancashire; Burdie House?
Ulodendron minus, Lindl. - (Lindl. Foss. Fl., t. 6.)	Woodcut, f. 1.	Do. do. - -	Edinburgh; Yorkshire; Durham.
Neuropteris gigantea, Sternb. (Brong., Hist. 1, t. 69.)		Do. do. - -	*Ballstone*, Coalbrooke Dale; Newcastle; Devon.
Sphenopteris Höningbausi, Brong. (Hist. 1, p. 199, t. 52.)	Woodcut, f. 2.	Do. do. - -	Newcastle; Germany; &c.
Alethopteris heterophylla, Lindl. (Foss. Fl., t. 38.)	- - -	Llwyd coed patch (A.)	Newcastle. *Ballstone*, Coalbrooke Dale.
Pecopteris oreopteridis, Brong. Hist. 1, t. 104, f. 2, t. 105, f. 1-3.)	- - -	Beaufort (A.) - -	*Ballstone*, Coalbrooke Dale; Shropshire; Bohemia; France; &c.
Pecopteris abbreviata, Brong. (Hist. 1, t. 115, f. 1-9.)	- - -	Do. do. -	*Ballstone*, Coalbrooke Dale; Bristol.

Fig. 1.

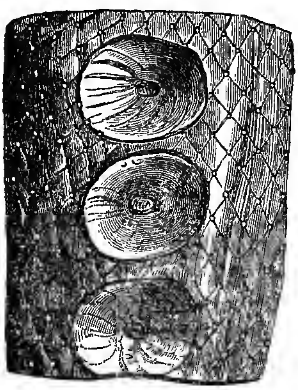


Fig. 2.

Fig. 1. Ulodendron minus, Lindl., one half the natural size.
Fig. 2. Sphenopteris Höninghausii, Brongn., Nat. size.

We have given figures of two of the more conspicuous fossils of this Ironstone which shows the unusual character of a mine full of plants, without shells or other fossils.

The "Ballstone" of Coalbrooke Dale is like it in its contents; the similarity is indicated by the above list. I scarcely suppose it can be the same band, but the coincidence is a striking one, and should be investigated. Perhaps collectors in South Wales will look carefully for remains of insects in this band of rock.

Dr. Bevan (Geologist, l.c.) has given a much more complete list of plants (named by Dr. Melville) from the Elled Coal. But these will be more properly considered when (as we hope soon will be the case) the Coals themselves and their fossils shall be illustrated; at present our attention is confined to the Iron-stones.

XII.—Black Pins Mine.
(Brackish or Marine ?)

—	Plate.	Localities in South Wales.	Other Localities.
Dadoxylon (Sternbergia) approximatum, Lindl.	- - -	Ebbw Vale (A.)	Newcastle, Shropshire.
Knorria Sellonii, Sternb. -	- -	Do. do.	Newcastle.
———, sp. - -	- - - -	Do. do.	
Halonia tortuosa, Lindl. -	- -	Do. do.	Shields; Coalbrooke Dale.
Anthracosia acuta, Sow. -	- - - -	Ebbw Vale (B.)	Coal, everywhere.

XIII.—Soap Vein Mine.
(Marine.)

—	Plate.	Localities in South Wales.	Other Localities.
Worm burrows, abundant -	Pl. 2, f. 8	Ebbw Vale (A.) - -	Everywhere.
Anthracomya Adamsii, n. sp. (*see* p. 66.)	Pl. 2, f. 7	Pen-y-cae (A.)	
Neuropteris Voltzii, Brong. var.? (Hist. pl. 67.)	- - -	Ebbw Vale (A.) - -	Strasbourg (Brong.)
Sphenopteris Hœninghausii - (Brong., Hist. pl. 52.)	Woodcut, p. 68.	Ebbw Vale (A.) - -	Newcastle; Germany.

Such worm burrows are very common through all the marine formations.. The habit of such marine worms is to traverse in all directions the carbonaceous silt or sand, swallow this in large quantities, extract its organic matter, and then return it comparatively pure. Hence the dark coloured silt is permeated in all directions by lighter coloured threads, frequently brought up from a lower bed or layer of different material. On the surface of the beds it is common to find two holes to each burrow, one for the entrance of water to the branchiæ, and the other presents a heap of rejected matter, known as worm casts. Our figure only represents the casts of the meandering burrows, which containing harder material than the bed itself, stand out in relief on the weathered surface.

The *Neuropteris*, if not a new species, is a very remarkable and beautiful variety of the *N. Voltzii*, Brongniart, a form not before discovered in Britain.

XIV.—Black Band.
(Marine.)

—	Plate.	Localities in South Wales.	Other Localities.
Modiola (or *Anthracomya*), small species.	Pl. 2, f. 1, 3	Blaina (A. B.)	
Megalichthys Hibberti, Ag. -	Pl. 2, f. 6	Do. (A.)	Burdie House; Leeds; Wigan, &c.
Rhizodus granulatus, Ag., the small intermediate teeth.	Pl. 2, f. 4, 5	Do. (A.)	See p. 58.

This completes the section, so far as the fossils in these collections are concerned. I have, however, from Mr. Adams, some specimens of the—

"PENNY PIECES,"
which Dr. Bevan believes to be on the level of the Soap Vein.

——	Plate.	Localities in South Wales.	Other Localities.
Anthracosia aquilina, Sow. -	Pl. 2, f. 17.	Ynys-cedwin, (A.)	
——— ovalis, Martin, or centralis? Sow.	- - -	Do. do. (A.)	
——— sp. with keeled ridges.	- -	Do. do. (Smyth)	

The following conclusions appear to be fairly deducible from the facts now stated :

1st. That there is a real distinction between the different beds of Ironstone, in regard to their fossil contents, and hence that we may hereafter use these fossils as means of identifying the strata in mine working.*

2nd. That the lower beds of the Coalmeasures in South Wales and Shropshire (and the same is true for Lancashire) contain a set of marine fossils, some of which are mountain limestone species, and the rest peculiar to the Coal measures.

3rd. There seem to be good reasons for supposing the "Rosser Veins" of South Wales equivalent to the "Pennystone" and underlying Ironstones of Coalbrooke Dale. The "Flint Coal Bass" has at least a very strong resemblance, in its fish remains, to the "Bottom Vein." The "Darran Pins" exactly resembles the "White Flats" of Coalbrooke Dale; and the 'Elled Balls Mine' is the counterpart of the "Ball Stone" of the same coalfield. The correlation of these beds must be determined more accurately when the coals themselves and their plants are examned.

4th. That the decidedly marine species diminish as we ascend in the section. But that their place is occupied by other (bivalve) shells, *Anthracomya, Modiola, Myalina?* which must have been inhabitants of salt, or at the least highly brackish water. And that as the *Anthracosiæ* (the common "Unio or mussel bands") are always in company with these, they also must be marine, and not fresh-water forms, as commonly supposed. They were mud-burrowing shells, with a wrinkled epidermis—like the *Myadæ.*

5th. Hence that there is no evidence, apart from the presence of ferns (for *Sigillaria, Lepidodendron,* and the *Coniferæ* may have grown in marine swamps), for the fresh-water origin of coal.

The above results, whatever they may be worth, are from my own observations on the coal fossils. That the sea water must have had frequent access to the coal growths, and that if the beds were not purely marine, they must at least have been

* See an admirable paper by Mr. Binney on the Lancashire coal field, and its connexion with other coal-fields. Quart. Geol. Journal vol. 2, p, 12.

estuary deposits, is a conclusion almost forced upon any observer. And this has been stated, with various degrees of force, by all the principal writers on coal.

The entirely marine origin of coal is by no means generally admitted. It was, however, long ago perceived, and most ably advocated, by the gentleman who of all others has paid most assiduous attention to the Coalmeasures in Britain. So far back as 1840 Mr. E. W. Binney published a somewhat elaborate paper in the Manchester Geological Transactions, Vol. 8,* "On the Origin of Coal." In that essay he pointed out the evidence of repeated subsidences, with periods of rest (not of elevation), throughout the whole duration of the British Coalmeasures. For the Lancashire coalfield—the one most under his own eye, and perhaps the most perfectly known in Britain—he showed that the lower Coal measures contain unmistakeable bands of marine fossils:—*Aviculopecten*, *Goniatites*, *Nucula*, squaloid fish, &c.;—that the middle and upper coal fields are more prolific in "*Unio*" bands and fish, &c.

But whether the contents of these bands be clearly marine, or doubtfully fresh-water, the same evidence of tranquil deposition of the floor or under-clay is visible. The same *Sigillariæ*, *Lepidodendra* and other coal plants are present; and hence he argues that, not only was the coal not drifted, for such a movement must have been accompanied by the transport of coarser sediment than fine mud, but that it is impossible to suppose the same flora could have flourished alike in fresh and salt water marshes, since a flora is at least as sensitive as a fauna to such changes. He concludes, therefore, that the water was of one kind, and more probably salt than fresh; while the fact of the Stigmaria roots being found so generally below the coal, shows that the great *Sigillariæ* could establish themselves in the sea mud while the fine sediment was depositing, and before the surface was fully fitted to receive the undergrowth which formed the mass of the coal.

Referring to the same point, the tranquil deposit over very large areas of uniform sheets of vegetable matter, Professor H. D. Rogers says:—"Only one particular process of accumulation "promises to explain the occurrence of these. I cannot conceive "any state of the surface but that in which the margin of the "sea was occupied by vast marine savannahs of some pea-"creating plant, growing, half immersed, on a perfectly horizontal "plain; and this fringed and interspersed with forests of trees, "shedding their leaves upon the marsh." l. c. p. 451. The author mentions numerous instances, and chiefly from the lower Coalmeasures, of purely marine remains in limestones upon, beneath, and mixed with the coal seams.

* In Vol. 1 of the same Transactions, Mr. Binney and Mr. Bowman had attempted to explain the origin of coal in a manner somewhat more akin to the usual idea, viz., that of estuary accumulation and of repeated elevations and depressions. The theory of the growth of coal on the spot where it is found, has been advocated so long, and proved so conclusively, by these and other authors, that it is unnecessary to refer to the numerous essays upon the subject. A very able summary of them, and many original statements, are to be found in Prof. H. Rogers' account of the Appalachian Coal Strata. Trans. of the Assoc. of American Geologists and Naturalists, for 1842.

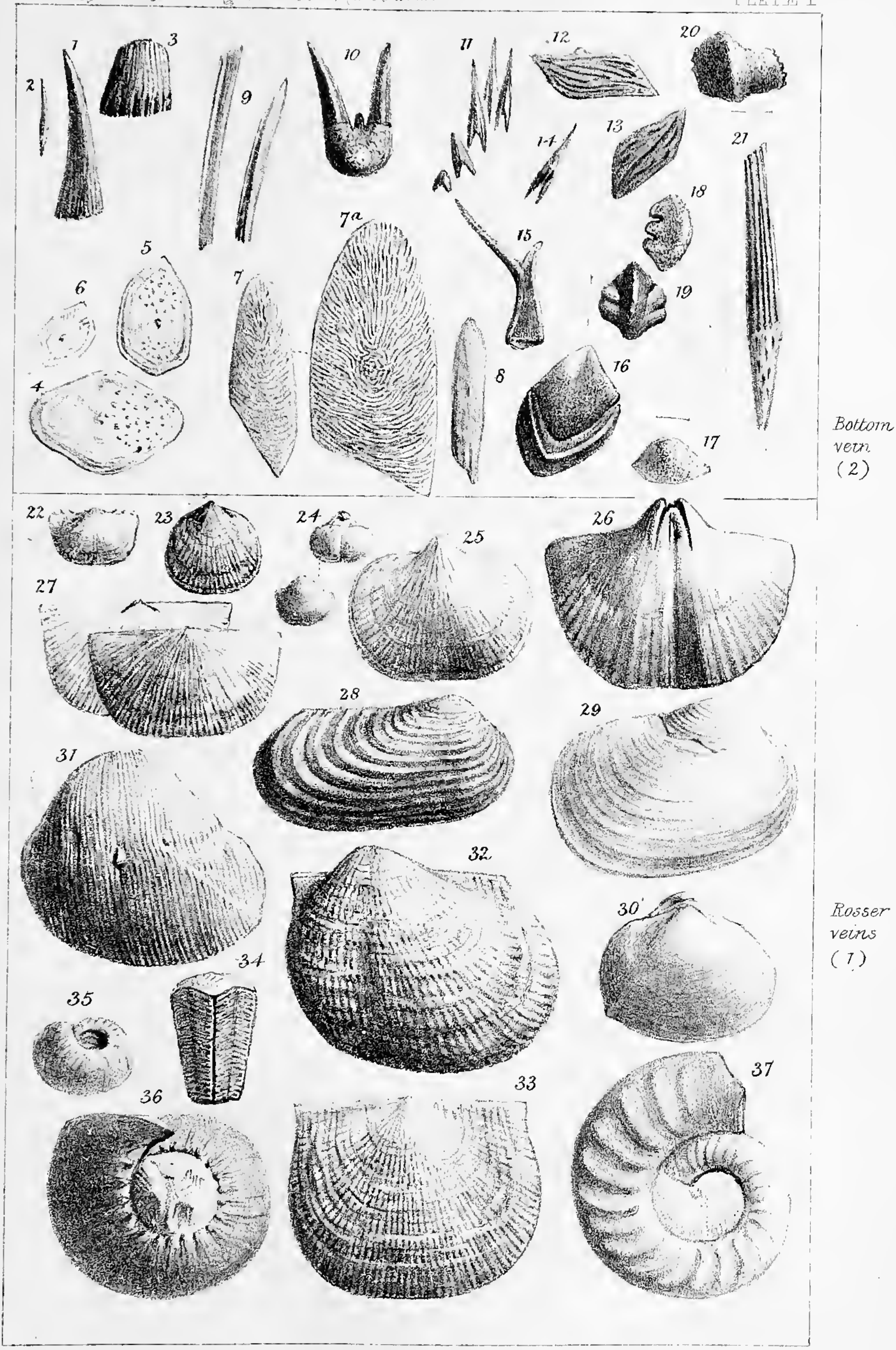
My friend, Mr. T. Rupert Jones, tells me that the supposed Cyprides of the Coalmeasures are quite as likely to be of a marine genus, and that some of them are certainly so.

It would appear, moreover, that Professor Agassiz and Prof. De Koninck have been of opinion that the "*Unio*" of the Ironstones was not of fresh water origin. I do not know that their views have been published. But if this be so, (and the observations above made, p. 62, may perhaps reconcile us to it,) and if it be true as I have shown, that the shells which accompany these "mussel bands" are allied to the marine *Myadæ*, or gapers, of our coasts—there will really be no room left for doubting the marine nature of all the animals, and the possibly marine character of all the plants—ferns alone excepted.

It would be out of place, in a short memoir on the Ironstone fossils of a particular section, to argue this point. The ferns certainly grew on the same spots with the *Sigillariæ*; and these, as several authors have shown, are often coated with the minute *Spirorbis*, which again is found mixed abundantly with true sea shells.

The land was not far off, on any theory. Mr. Godwin Austen* has shown us the outline of the great North European Bay, which was fringed by our own and the German coal-growths. The researches of Mr. Sorby, whose observations on the current-marks would go to prove a limited extension (for our area) of the ocean basin in the Coalmeasure period, and the production of a series of shallow and partially enclosed seas, have been pointedly referred to in the Appendix to the last edition of "Siluria," p. 570. In that note the probable nature of the ancient shore, with its vast swampy forest of water-loving plants, protected from the tidal action by sandbars, and therefore in the condition of great maritime lagoons, is discussed, and this view is advocated. In such 'putrid' seas, accumulations of black shale and fœtid limestone would be a normal state of things—the carbonic acid generated by decomposition of the plants would readily unite as a bi-carbonate with whatever iron were present in the water, and be precipitated, as a carbonate of iron, in the form of "Ironstone." We should have sea inhabitants—different from those found within tide-marks on ordinary shores. Races of mollusca, fitted for burrowing and living in such localities, with annelides to devour the decaying vegetable matter, would be abundant, and perhaps would be the only tenants of the bottom. The epiphytal ferns which grew on the decaying trees, and such water- or land-insects as could find a home in the hollow stumps, together with a few aquatic and possibly even terrestrial lizards, would all find an appropriate residence in the swamp, and contribute their spoils to the future coal-bed.†

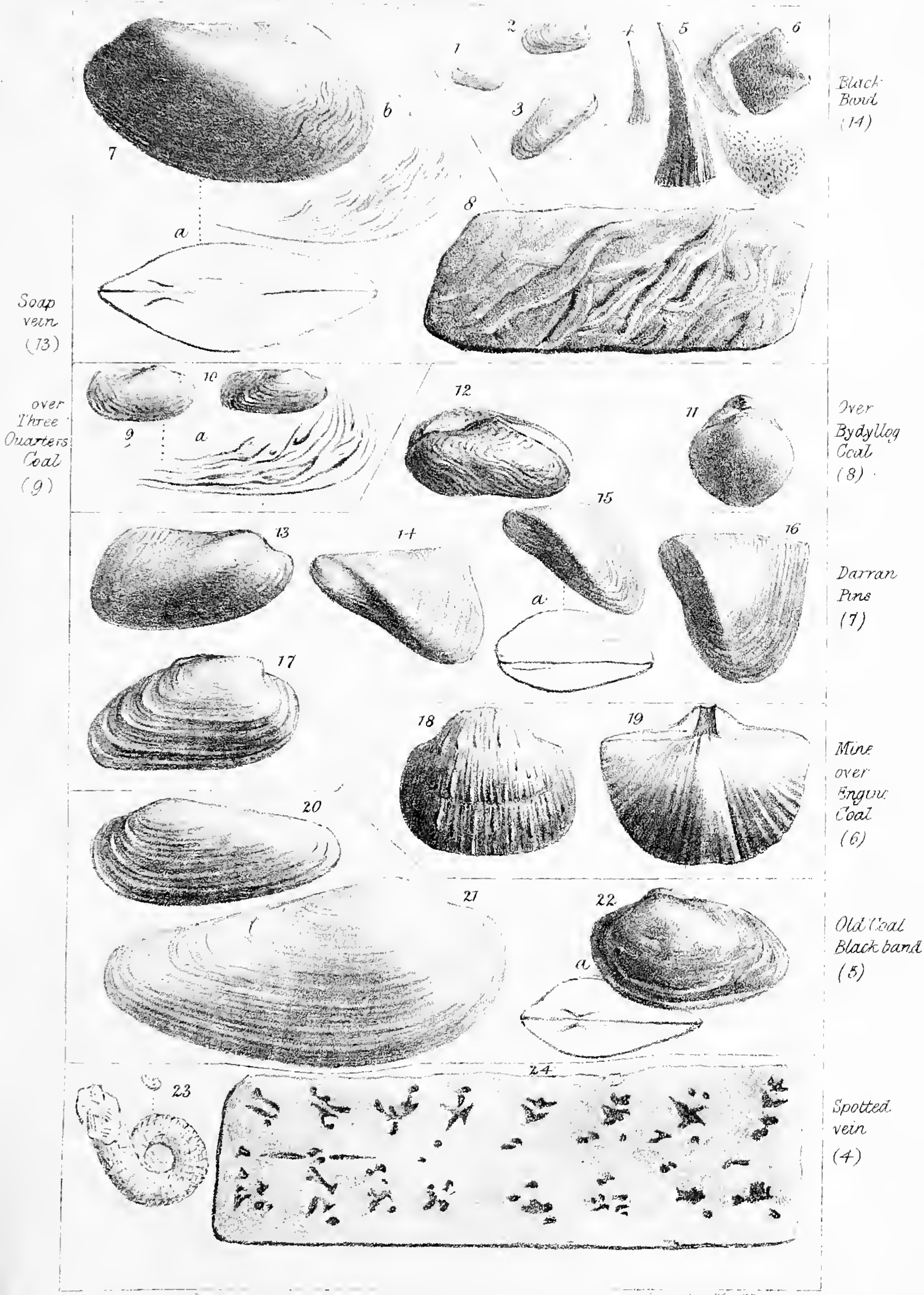
* Quart. Geol. Journal, Vol. II., 533.
† See also Mem. Geol. Surv., vol. 1. p. 311.



C. R. Bone del. et lith.

Day & Son Lithrs to The Queen

FOSSILS OF THE IRONSTONES_S. Wales.



FOSSILS OF THE IRONSTONES _ S Wales.

PART IV.

Iron Ores of the Shropshire Coal Field.

General Description. (By Warington Smyth, M.A., F.R.S.)

The tract of Coal-measures extending southward from Newport to the east of the town of Wellington, and down to the neighbourhood of Broseley, is one of the smaller among the important coal-fields of Great Britain, but has been honourably distinguished for the quantity and quality of the iron which it produces.

Its general outline is that of a triangle, of which a very acute angle terminates near Newport, and of which the length may be taken at about 12 miles, and the greatest breadth at 4 miles. But whilst its western edge, for a great part of this length, is definitely limited by its outcrop, where the carboniferous strata rest upon older or upon intrusive rocks, the eastern side dips under a cover of the Red Sandstones of the Permian formation, and has already been extended by workings beneath certain superimposed rocks, which were in former years supposed to form its actual limits. The existence of faults or interruptions of the regularity of the seams almost coincident with the commencement of this Red Sandstone cover added probability to this earlier view. But more recent explorations, among which should be especially noted those of Stirchlee, described by Mr. Marcus Scott, F.G.S., in great detail in the Quarterly Journal of the Geological Society, vol. xvii., have satisfactorily proved the underground continuation of the coal-field beyond the line where it was formerly supposed to be lost.

Once cognizant of this fact, we cannot but speculate upon that question which will ere long be one of paramount importance to this country, the extension of the Coal-measures with workable regularity beneath those vast tracts of the Red Sandstone which occupy so large a portion of the surface in the counties of Warwick, Stafford, Salop, and Chester. Let any one on a clear day ascend the Wrekin, to the west of the coal district now described, and raise his view above the foreground of pits and waste-heaps and mounds of slag and blazing furnaces, and glance over the undulating fertile tract of Red Sandstone which for some sixteen miles in width separates the works of Priorslee and Madeley from the district of Wolverhampton. In the dim distance his eye will rest on the smoke of the forges, pits, and furnaces of the South Staffordshire coal-field, and his attention must be

rivetted to the great probability, considering the position of the strata and the form of the ground, of the real continuity, in spite of occasional fractures, of these valuable deposits of the Carboniferous period. A closer examination of the details of the composition of the two coal-fields will strongly tend to confirm these first impressions; for although points of great divergence in character will have to be noticed, many striking analogies present themselves; and, perhaps, some of the most convincing features of resemblance are those which will be brought to light by a careful comparison of the iron ores.

An excellent general description of the East Shropshire or Coalbrookdale coal-field, comprising a number of detailed sections of the strata, has been given by Mr. J. Prestwich, F.R.S., in the Transactions of the Geological Society, 2nd series, vol. v. This, with the map and engraved sections of the Geological Survey, supply us with such an insight into the structure of the district that we need in this place but insert a single section for the purpose of referring to their proper places the iron ores which form the subject of the following analyses.

The coal-field is crossed in an east and west direction by the Wolverhampton and Shrewsbury railway, by the excellent high road which was once the main thoroughfare to Holyhead, and by the river Severn, in the deep valley of which some instructive natural exposures of the rock may be seen. Of the lower measures a good view may be obtained in the upper end of the Coalbrook dale, and in the uneven ground of the western side of the field, but the condition of the upper measures, partly from the natural smoothness of the ground on the east, and partly from the rarity of excavations there, is obscure and difficult of study.

It is for this reason that one is unable very definitely to lay down the total thickness of the coal-series, although it may be asserted, with some confidence, that it does not exceed 1,200 feet, into the lower fourth part of which all the known useful beds of coal and ironstone will fall. The thickness given by most of the sinkings is considerably less, but looking at the unconformity of the superposition of the red sandstones, it is possible that the uppermost part of the coal-measures is not seen, and, moreover, the higher portions already known are of an exceedingly variable character.

Among such variations, which are for so small a district unusually marked and abrupt, may be mentioned that of the basis of the Coal-measures, the Carboniferous Limestone, which, although it appears in considerable thickness at Lilleshall and at Steeraways, has entirely died out at the southern extremity of the field, so as to allow the coal to rest immediately on the Silurian rocks. The thickness of the total body of the measures, as well as that of the individual beds, also decreases rapidly as we pass from north to south; thus, the total thickness of coal varies from 55 feet at Donnington to 40 at Lightmoor, and 16 at Amies, near Broseley, and the number of the seams is similarly

diminished. The ironstone measures, which are 72 feet thick and 7 in number at Donnington, decrease to 24 feet and three measures at Lightmoor, and to 8 feet and two measures at Broseley, south of which town all the ironstones are represented by a single bed, the Crawstone, the lowest in the series.

It is thus evident that a section taken from either extremity of the field would give no idea of its average contents, and unless we add to one of the northern sections the particulars of certain beds, as exhibited in the south of the area, we should be unable to give a conspectus of the position of all the ironstones. Whether a similar variability will assert itself in an east and west direction is a momentous question, not only on account of the general interest of the continuity of the measures eastward, but from the fact that a large portion of this excellent coal-field has been absolutely exhausted, and that only a narrow strip of the old recognized area remains, which a few years of our present active working will reduce within extremely small limits.

The following section at Wombridge pits was first given by Dr. Townson (Prestwich, p. 475):—

		yds.	ft.	in.
Top rock	Argillaceous yellowish sandstone	9	0	0
White clay	Blackish grey plastic clay	6	0	0
Chance COAL	Common coal	0	0	9
White tough	Blackish grey plastic clay	0	2	0
Ash-ball rock	Mixed small fragments of greenish clay, &c.	6	0	0
Rocky marl	Reddish brown dry shivery clay	6	0	0
Gritty rock	White, very fine or compact sandstone	2	0	0
Rocky marl	Mixed small fragments	4	1	0
Gritty rock	Fine grey sandstone, with mica	1	2	0
Rocky marl	Reddish brown and whitish clay	3	0	0
Gritty rock	Whitish sandstone	1	1	0
Ash ball measure	Fragmentary greenish clay and quartz	28	0	0
White rock	Very fine white sandstone	1	0	0
Rocky marl	Similar to former	3	2	0
Rock	Very fine sandstone	0	2	0
Tough soft clay	Blackish grey plastic clay	0	1	6
Hard rock	Grey fine sandstone, small particles of mica	1	1	0
Top *Penny measure*	Ironstone in blackish grey clay	2	2	0
Black slums	Greyish black slippery clay	0	1	6
Fungous Coal rock	Coarse whitish sandstone	12	0	0
Fungous COAL	Excellent coal	1	0	0
Fungous coal poundstone	Greyish black clay	1	1	0
Foot COAL	Not got	0	1	0
Black stone (Anal. LXXX.)	Ironstone nodules in greyish black clay	1	1	0
Stone COAL	Good coal	1	1	0
Tough poundstone	Black slippery clay	1	0	0
Gur COAL	Not got	0	2	0
White clunch	Blackish grey clay	1	1	0
Grey rock	Light grey fine sandstone	1	1	0
Brick measure	Alternating grey ironstone and clay	5	1	0
Bind bass	Black dry clay	2	0	0
Bind	Brownish grey fine argillaceous sandstone	2	1	0
Ballstone	Grey ironstone nodules in clay	3	0	0
Dun earth	Ditto in grey clay	2	0	0
Top coal bass	Black indurated schistose clay	0	0	4
Top COAL	One of the best coals in Shropshire	1	2	0
Top coal poundstone	Greyish black slippery clay	0	1	0
Slums	Black slippery clay	1	1	0
Three-quarter COAL	Never got	0	2	0
Double coal rock	Very fine whitish sandstone	2	0	0

		yds.	ft.	in.
Double COAL - -	Much used - - - -	2	0	0
Double coal poundstone -	Greyish black clay - - -	0	1	6
Yellowstone - - -	Ironstone, in short thick masses, in grey clay	2	0	0
Yard COAL - - -	Sometimes got - - - -	1	0	0
Yard coal poundstone	Black clay resembling bass - - -	0	0	9
Quoice neck - -	Greyish black clay, with shining surfaces	0	0	9
Blue flat (Anal. LXXXI.)	Brownish ironstone in clay	2	0	0
Pitcher basses -	Indurated schistose clay - -	1	2	0
White flat (Anal. LXXXII.)	Ironstone in shivery grey clay	1	1	0
Flint coal rock -	Fine whitish sandstone, with mica	3	1	0
Flint coal roof - -	Blackish grey clay - - -	4	1	0
Flint COAL - -	Good burning coal - - -	1	2	0
Flint - -	Fine-grained sandstone, used for building -	7	0	0
Penny measure (Anals. LXXXIII., LXXXIV., LXXXV.)	Blackish grey clay, with ironstone -	8	0	0
Sulphur COAL ·	Pyritous coal, used for lime and brick burning	1	2	0
Sulphur coal bass - -	Greyish black clay - - -	0	1	6
Upper clunch COAL	Good coal, not got underground	0	0	10
Upper clunch -	Light grey clay, used for fire bricks -	1	0	0
Clunch COAL - -	Never got -	0	2	0
Lower clunch -	Grey fire-clay - -	2	0	0
Two-foot COAL -	Sometimes got - - -	0	2	0
Linseed earth - -	Black grey clay, used for fire bricks -	4	0	0
Best COAL - -	In the northern part 9 inches, but in the southern -	0	2	0
Randle COAL - -	The best smith's coal - -	1	0	0
Bannock -	Brownish grey clay, good for fire brick -	0	2	0
Clod COAL -	Largely used for iron smelting	1	1	0
Pale blue clod	Blueish grey clay - - -	1	1	6
Sandstone -	Fine argillaceous sandstone	3	0	0
Little flint COAL	Good burning coal -	0	2	0
Little flint	Very fine white sandstone -	3	1	0
		179	0	11

Below this may be added from the Madeley Sections :—

		yds.	ft.	in.
Crawstone measure (Anal. LXXXVI.)	Fine sandstone, with ironstone -	1	0	0
COAL under ditto - -	Slate coal -	0	1	0
Crawstone crust -	Whitish fine sandstone -	1	2	7
Lancashire ladies COAL -	Fibrous coal - - -	0	0	9
Rock, very hard - -	White sandstone, with quartz pebbles - -	0	2	0
Ditto - - -	Compact white argillaceous sandstone -	1	0	0

This last immediately overlies the Wenlock limestone at Lincoln Hill.

SPECIAL DESCRIPTION OF THE IRONSTONES.

(Museum of Practical Geology, wallcase 54, shelf 6.)

It will have been observed that the upper strata of this coal-field are remarkably wanting in workable seams of coal or ironstone. The first measure of the latter which is reached in the sinkings is the *Top* or *Chance Pennystone,* a deposit occurring with much irregularity, but possessing a strong general resemblance to the main Penneystone which lies about 200 feet deeper. One of the most interesting features in the Shropshire ironstones is the great variety of fossil remains preserved in the interior of the nodules, exceeding in this respect those of most other known districts. The Chance Pennystone contains the

bivalve called *Productus scabriculus* in great numbers, *Conulariæ,* and the remains of at least two species of fish.

The *Ragged Robin* is a very irregular ore underlying the Fungous coal.

The *Blackstone* measure [Anal. LXXX.], is an ironstone of dull lustre and irregular fracture, but having smooth shining and very black surfaces above and below the nodules. White spots, and cylindrical cavities filled with a white powder, are commonly observable, and the form of the latter denotes them in many cases to have been occasioned by the rootlets of *Stigmariæ.* Small *Lingulæ* and remains of fish have been found in it. The Blackstone will yield about 1,500 tons to the acre, and is highly valued as one of the materials for making the "best best" cold blast iron.

Brick Measure, an ironstone of secondary importance, occurring in flat cakes of a rich brown, with their surfaces very smooth and of a chocolate colour. Planes of cleavage run very regularly through them, dividing them into brick-like masses very like the 'white flats' of South Staffordshire.

Ballstone.—The nodules of this measure are large, and "remarkable," as Mr. Prestwich states, "for the abundance and beauty of the vegetable reliquiæ,"* whilst they appear to contain few animal remains. In passing southward it entirely disappears. It possesses a brownish grey colour and conchoidal fracture, and is one of the materials used for the production of the best iron.

Yellowstone, a lumpy, irregular nodule with white powdery spots; turning out where well developed 1,200 tons to the acre, of average value, although costing more than most of the other stones to get, and employed both for hot and for cold blast iron. Vegetable remains and "*Unio*" (*Anthracosia*) occur in this bed.

Blue Flats. [Anal. LXXXI.]—Brownish grey irregular nodules with many markings of Stigmaria rootlets, and interspersed portions of indurated clay; contains *Anthracosia* and remains of plants. It yields 1,600 tons to the acre, and is worth on the average, like the above ironstones, 16*s.* per ton, whilst the cost of getting, in 1860, may vary from 8*s.* to 11*s.* per ton. I am informed by Mr. Edward Jones, manager of the extensive works of the Lilleshall Company, which makes about half the production of the county, that their cold-blast iron, known to bear a very high character, is made from equal mixtures of Blackstone, Ballstone, Blue Flats, and Pennystone. Similar ores are used for the hot-blast iron, but with an admixture of 40 per cent. of hæmatite.

White Flats. [Anal. LXXXII.]—Brownish grey nodules with the surfaces of a lighter colour than the last. It is very rich in fossils:—five species of *Anthracosia* (or "*Unio*") and some aviculoid shells characteristic of the coal,† teeth and spines of

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* Upwards of 50 species are catalogued by Prestwich from this bed alone!

† The reader will find some of these characteristic shells, like *Avicula, Modiola,* and *Unio,* but of distinct genera, figured in Part III. of the "Iron Ores." They are from Ebbw Vale specimens, but exactly the same as those of Coalbrookdale.

Megalicthys and *Gyracanthus*, trilobitoid crustaceans (*Limulus*), and abundant plant remains (25 species) are imbedded in them. The measure yields about 1,500 tons to the acre, selling at a somewhat lower price than those already mentioned.

Penny or Pinney stone. [Anals. LXXXIII. IV. V.]—This very remarkable series of nodules produces from 2,200 to 2,600 tons to the acre where well developed, but as already observed thins out greatly in its passage to the southern part of the field. At the same time, whilst almost barren of organic remains in the northern portion of the district, it becomes as it approaches the Severn a perfect museum of well-preserved animal and vegetable fossils.

Among the more noticeable of the former are the species of *Anthracosia, A. subconstricta, A. robusta, A. aquilina, A. acuta; Anthracomya* and *Myacites*, several species; very numerous examples of *Anthracoptera quadrata, Axinus* (formerly *Venus*) *carbonarius* and *A. sulcatus, Ctenodonta æqualis, Spirifer bisulcatus, Lingula mytiloides, Productus scabriculus, Discina nitida,* &c.; more rarely, *Goniatites, Bellerophon, Natica, Pleurotomaria, Orthoceras* (*Nautilus* is more common), and the remains of fishes of at least five genera.

The pennystone nodules are generally small, brown, and with an irregular fracture: frequently containing calc-spar in thin films filling cracks of contraction, as well as a white powder, which is sometimes sulphate of baryta, at others hydrous silicate of alumina.

The extensive piles, in which the ironstone is stacked at the surface in order to allow it by weathering to be easily freed from shale, allow of an easy inspection of large quantities of it; and perhaps nothing is more striking than the evidence that when in a soft state it has been pierced by burrowing worms, which have left heaps of excretions at the doors of their dwellings. The surface indeed of some of the flat nodules diversified by these little mounds, and by tracks and small markings of many kinds, reminds one strongly of the muddy or silty flats on some of our own shores. The tubular cavities are now filled, sometimes with earthy matter, and sometimes with zinc-blende, a metallic mineral which, in a brilliantly crystalline state, often accompanies the vegetable remains.

Evidence so conclusive, of the formation of this blende or sulphide of zinc from watery solution, is seldom to be obtained.

At some of the works this ironstone is employed alone for the smelting of iron, and produces an excellent pig. The measure is in some parts of the field divided into a Top or Main and a Bottom Pennystone, which latter is said to give 900 tons per acre in addition to the quantity cited above. This latter rests on the "Sulphur" or "stinking coal;" and a comparison of the measures resting on a similarly named coal-seam in the South Staffordshire district may be made by reference to the Iron Ores, Part. II., p. 104, and p. 111; whence the importance of the ana-

logy obtained by position and contents of the beds, as bearing on the question of the unity of the coal-field, will at once appear.

Crawstone. [Anal. LXXXVI.]—This, the lowest ironstone of the series, excepting a "chance" stone which has been found in a few pits in Madeley parish, is a singular looking brownish, often rough-grained nodule occurring imbedded in finely granular sandstone. The surface of cracks and fissures in it is often varnished over with a crystalline film of carbonate of iron, and spotted with crystals of zinc-blende. It was said to make an unusually strong iron when largely worked in the southern part of the field, but in the northern it is quite unknown, and from its exhaustion in many of the old pits on the sides of the Severn valley is no longer accounted an ore of importance.

Mr. Salter, who has revised the above list of fossils, informs me that this ironstone has been known to contain *Anthracosia* and *Anthracoptera* (*Myalina* of some authors).

The following were the iron-works of this district, in 1860:—

Dawley Castle	- Coalbrookdale Company	- 2	furnaces.
Dark Lane -	- Beriah Botfield, M.P.	- 2	„
Horsehays -	- Coalbrookdale Company	- 2	„
Hinkshay -	- Beriah Botfield, M.P.	- 2	„
Ketley - -	- The Ketley Company	- 2	„
Langley Field -	- Beriah Botfield, M.P.	- 1	„
Lawley - -	- Coalbrookdale Company	- 1	„
Lightmoor -	- Coalbrookdale Company	- 2	„
Lodge Wood -	- Lilleshall Company -	- 4	„
Madeley Court	- J. Bradley and Co. -	- 3	„
Madeley Wood	- Madeley Wood Company	- 3	„
Priorslee -	- Lilleshall Company -	- 4	„
Old Park -	- Old Park Company -	- 4	„
	Total - -	- 32	„

of which 26 were in blast.

The produce of pig-iron was 145,200 tons.

LXXX.—Black Flats, Shropshire.

(By J. Spiller.)

(No. 177 of the Illustrated Catalogue.)

Description.—Clay ironstone, easily scratched by a steel point; colour, dark gray; fracture, sub-conchoidal; structure, minutely crystalline. The specimen contains a small quantity of white clay distributed in the cavities of contraction.

Analysis by Method No. III.

Water, hygroscopic and total amount:—	grs.
50·515 grs. of ore lost of water at 100° C. - -	0·12
24·31 grs. of ore yielded of water at a red heat -	0·21
By the action of hydrochloric acid:—	
19·575 grs. of ore gave of—	
Insoluble residue (ignited) - - - -	2·19
Manganoso-manganic oxide (Mn_3O_4) - -	0·17
Alumina - - - - -	0·13
Sulphate of lime - - - -	1·075
Pyrophosphate of magnesia - - - -	1·005

The insoluble residue (ignited) gave of—	grs.
Silica	1·44
Alumina	0·685
Peroxide of iron	0·105
Sulphate of lime	0·04
Ammonio-phosphate of magnesia	trace.
30·72 grs. of ore gave of—	
Organic matter	0·19
Chloride of potassium	0·05
Phosphoric and sulphuric acids, and bisulphide of iron:—	
39·30 grs. of ore gave of—	
Pyrophosphate of magnesia	0·16
Sulphate of baryta (from sulphates)	0·11
Sulphate of baryta (from bisulphide of iron)	0·28
27·125 grs. of ore gave of carbonic acid	8·945

Iron, by standard solution of bichromate of potash:—
Standard: 1 gr. of iron = 8·45 cub. cent. of solution.

Iron, total amount (soluble in hydrochloric acid):—

	Weight of ore.	Cub. cent. of solution.	Per cent. iron.
I.	9·74	30·9	37·55
II.	9·65	30·6	37·52

A very small quantity of the iron existed in the state of peroxide.

Results tabulated.

Protoxide of iron	48·28
Protoxide of manganese	0·82
Alumina	0·67
Lime	2·26
Magnesia	1·83
Carbonic acid	32·98
Phosphoric acid	0·26
Sulphuric acid	0·10
Bisulphide of iron	0·19
Water, hygroscopic	0·24
Water, combined	0·62
Organic matter	0·62
Ignited insoluble residue	11·19
	100·06

Ignited Insoluble Residue.

Silica	7·36
Alumina	3·50
Peroxide of iron	0·53
Lime	0·08
Magnesia	trace.
Potash	0·10
	11·57

Iron, total amount	37·92

None of the metals precipitable by sulphuretted hydrogen from the hydrochloric-acid solution, were detected in 820 grains of the ore.

LXXXI.—Blue Flats, Donnington Wood, Shropshire.

(By J. Spiller.)

(Nos. 170 and 171 of the Illustrated Catalogue.)

Description.—Clay ironstones, easily scratched by a steel point; colour, dark brownish gray; fracture, sub-conchoidal; structure, compact. Both ores contain veins of clay irregularly disposed; No. 170 blende; and No. 171 a few very thin films of iron pyrites.

A mixture of equal weights of the two ores was taken for analysis.

Analysis by Method No. III.

Water, hygroscopic and total amount:—	grs.
I. 56·66 grs. of ore lost of water at 100° C. -	- 0·155
II. 31·285 grs. of ore gave of water at a red heat -	- 0·34
By the action of hydrochloric acid:—	
22·59 grs. of ore gave of—	
Insoluble residue (ignited) - - -	- 2·99
Manganoso-manganic oxide ($Mn_3 O_4$) -	- 0·20
Alumina - - -	- 0·11
Sulphate of lime - - -	- 1·255
Pyrophosphate of magnesia - -	- 1·265
The insoluble residue (ignited) gave of—	
Silica - - - - -	- 1·86
Alumina - - - - - -	- 0·855
Peroxide of iron - - - -	- 0·155
Oxalate of lime - - - -	- trace.
Pyrophosphate of magnesia - -	- 0·045
46·64 grs. of ore gave of—	
Organic matter - - - -	- 0·29
Chloride of potassium - - -	- 0·24
Phosphoric and sulphuric acids, and bisulphide of iron:—	
34·40 grs. of ore gave of—	
Pyrophosphate of magnesia - -	- 0·265
Sulphate of baryta (from sulphates) -	- 0·11
Sulphate of baryta (from bisulphide of iron)	- 0·10
I. 20·235 grs. of ore gave of carbonic acid -	- 6·41
II. 26·265 „ „ „ - -	- 8·295

Iron, by standard solution of bichromate of potash:—
Standard: 1 gr. of iron = 8·45 cub. cent. of solution.

Iron, total amount (soluble in hydrochloric acid):—

	Weight of ore.	Cub. cent. of solution.	Per cent. iron.
I.	10·22.	31·1	36·01
II.	9·06.	27·5	35·92

No experiment was made to determine the amount of the iron, usually very small, which exists in the state of peroxide.

Results tabulated.

Protoxide of iron - -	46·30
Protoxide of manganese - -	0·82
Alumina - - - -	0·48
Lime - - - -	2·30
Magnesia - - -	2·01

Carbonic acid	31·68
Phosphoric acid	0·50
Sulphuric acid	0·11
Bisulphide of iron	0·08
Water, hydroscopic	0·28
Water, combined	0·81
Organic matter	0·62
Ignited insoluble residue	13·24
	99·23

Ignited Insoluble Residue.

Silica	8·23
Alumina	3·78
Peroxide of iron	0·69
Lime	trace.
Magnesia	0·07
Potash	0·33
	13·10
Iron, total amount	36·49

Zinc-blende and a distinct trace of copper were found in the ore.

LXXXII.—White Flats, Donnington Wood, Shropshire.

(By J. Spiller.)

(No. 172 of the Illustrated Catalogue.)

Description.—Clay ironstone, easily scratched by a steel point; colour, light brownish gray; fracture, sub-conchoidal; structure, compact. The specimen bears an impression of fossil wood, and is permeated in some parts by veins of shale. The sample selected for analysis was free from shale.

Analysis by Method No. III.

	grs.
Water, hygroscopic and total amount:—	
41·55 grs. of ore lost of water at 100° C.	0·145
25·53 grs. of ore yielded of water at a red heat	0·33
By the action of hydrochloric acid:—	
32·425 grs. of ore gave of—	
Insoluble residue (ignited)	4·705
15·96 grs. of ore gave of—	
Insoluble residue (ignited)	2·29
Manganoso-manganic oxide (Mn_3O_4)	0·17
Alumina	0·145
Sulphate of lime	1·11
Pyrophosphate of magnesia	0·88
The insoluble residue (ignited and weighing 2·29 grs.) gave of—	
Silica	1·58
Alumina	0·575
Peroxide of iron	0·09
Sulphate of lime	0·04
Ammonio-phosphate of magnesia	trace.

47·32 grs. of ore gave of—	grs.
Organic matter - - - -	0·18
Chloride of potassium - - -	0·18

Phosphoric and sulphuric acids, and bisulphide of iron :—

74·47 grs. of ore gave of—	
Pyrophosphate of magnesia - -	0·81
Sulphate of baryta (from sulphates) - -	0·135
Sulphate of baryta (from bisulphide of iron) -	0·035

I.	21·18 grs. of ore gave of carbonic acid - -	6·55
II.	16·775 „ „ - - -	5·15

Iron, by standard solution of bichromate of potash :—

Standard : 1 gr. of iron = 8·45 cub. cent. of solution.

Iron, total amount (soluble in hydrochloric acid) :—

	Weight of ore.	Cub. cent. of solution.	Per cent. iron.
I.	9·71	28·9	35·22
Iron, as protoxide :—			
II.	7·32	21·3	34·44
III.	11·26	32·8	34·48

Results tabulated.

	I.	II.
Protoxide of iron - -	44·33	44·28
Peroxide of iron - -	1·06	
Protoxide of manganese - -	1·00	
Alumina - - - -	0·92	
Lime - - - -	2·86	
Magnesia - - -	1·97	
Carbonic acid - - -	30·92	30·70
Phosphoric acid -	0·70	
Sulphuric acid - - -	0·06	
Bisulphide of iron -	0·01	
Water, hydroscopic - -	0·35	
Water, in combination - -	0·95	
Organic matter - -	0·38	
Ignited insoluble residue -	14·35	14·51
	99·86	

Ignited Insoluble Residue.

Silica - - - -	9·90
Alumina - - -	3·60
Peroxide of iron - - -	0·56
Lime - - - -	0·12
Magnesia - - -	trace.
Potash - - -	0·24
	14·42

Iron, total amount - - -	35·61

A minute trace of a reddish metal, probably copper, though too small to identify, was detected in 480 grs. of the ore.

LXXXIII.—Pennystone, Donnington Wood, Shropshire.

(By J. Spiller.)

(No. 173 of the Illustrated Catalogue.)

Description.—Nodular clay ironstone, easily scratched by a steel point; colour, pale brownish gray; fracture, sub-conchoidal; structure, compact. The nodule has veins of contraction filled with white crystals of sulphate of baryta, and a white pulverulent form of the same substance. The analyses of these are subjoined. Small scattered particles of iron pyrites are sparingly distributed over the surface of the sulphate of baryta crystals, and the internal cavities of the ironstone.

Analysis by Method No. I.

Water, hygroscopic and total amount:—	grs.
28·27 grs. of ore lost of water at 100° C. - -	0·085
72·14 grs. of ore gave of water at a red heat - -	0·735
By the action of hydrochloric acid:—	
200·06 grs. of ore gave of—	
Insoluble residue (ignited) - - - -	16·82
Sulphate of baryta (from sulphates) - -	trace.
10·47 grs. of ore gave of—	
Peroxide of iron - - - - -	5·305
Manganoso-manganic oxide (Mn_3O_4) -	0·19
Alumina - - - - - - -	0·045
Silica (precipitated with the peroxide of iron) -	0·06
Carbonate of lime - - - -	0·55
9·725 grs. of ore gave of—	
Peroxide of iron - - - -	4·93
Manganoso-manganic oxide - -	0·185
Alumina - - - - - - -	0·035
Silica (precipitated with the peroxide of iron) -	0·05
Carbonate of lime - - - - -	0·485
Pyrophosphate of magnesia - -	1·115
10·395 grs. of ore gave of—	
Insoluble residue (ignited) - - -	0·865
Pyrophosphate of magnesia - -	1·20
3·65 grs. of the insoluble residue (ignited) gave of—	
Silica - - - - - - -	2·465
Alumina - - - - - -	0·855
Peroxide of iron - - - -	0·255
Carbonate of lime - - - -	0·125
Pyrophosphate of magnesia - -	0·11
Phosphoric and sulphuric acids, and bisulphide of iron:—	
89·77 grs. of ore gave of—	
Pyrophosphate of magnesia - - -	0·64
I. 68·66 grs. of of ore gave of—	
Sulphate of baryta (from sulphates) - -	trace.
Sulphate of baryta (from bisulphide of iron)	1·29
II. 42·55 grs. of ore gave of—	
Sulphate of baryta (from bisulphide of iron) -	0·80
26·45 grs. of ore gave of—	
Organic matter - - - - -	0·06
Chloride of potassium - - - -	trace.
I. 29·02 grs. of ore gave of carbonic acid - - -	9·88
II. 27·30 " " " - - -	9·28

Iron, in the state of peroxide (by Fuchs' process):—	grs.
36·89 grs. of ore were dissolved in hydrochloric acid, a weighed slip of electrotype copper introduced, and the solution left at the ordinary temperature for four days, air being excluded.	
Weight of copper dissolved - - -	0·165

Results tabulated.

	I.	II.
Protoxide of iron - -	45·08	45·12
Peroxide of iron - -	0·55	
Protoxide of manganese - -	1·69	1·78
Alumina - - -	0·43	0·35
Lime - - -	2·95	2·80
Magnesia -	4·11	4·08
Carbonic acid - - -	34·04	34·00
Phosphoric acid - -	0·46	
Silica, soluble in hydrochloric acid	0·57	0·52
Sulphuric acid - -	trace.	
Bisulphide of iron - -	0·48	0·49
Water, hydroscopic -	0·30	
Water, combined - -	0·72	
Organic matter - -	0·23	
Ignited insoluble residue -	8·32	8·38
	99·93	

Ignited Insoluble Residue.

	I.
Silica - - - -	5·66
Alumina - - -	1·96
Peroxide of iron - -	0·26
Lime - - - - -	0·16
Magnesia - - -	0·09
Potash - - - -	trace.
	8·13
Iron, total amount - - -	35·63

Analysis of the white crystals and powder from the interior of clay ironstone, No. 173 of the illustrated catalogue.

A weighed portion of the powdered crystals was fused with a mixture of the carbonates of potash and soda, and the fused mass treated with water; the insoluble carbonate of baryta collected on a filter, washed, dissolved in dilute hydrochloric acid, the solution heated, and the baryta precipitated by sulphuric acid; the sulphate of baryta so obtained was collected, ignited, and weighed in the usual manner,

The aqueous solution, the filtrate from the carbonate of baryta, was evaporated to dryness with excess of hydrochloric acid, moistened with the same acid, and dissolved in water; a small quantity of silica left insoluble was collected and weighed. The sulphuric acid in the solution was next precipitated by chloride of barium, the sulphate of baryta weighed as a control upon the former result. The filtrate was tested for alumina by removing the excess of baryta from solution by means of sulphuric acid, and adding ammonia; a very small quantity of alumina was indicated.

8·11 grs. of the dried mineral gave of—	grs.
Sulphate of baryta (from baryta) - - -	7·98
Sulphate of baryta (from sulphuric acid) - -	7·99
Silica - - - - - - -	0·07
Alumina - - - - -	0·015
Peroxide of iron - - - -	trace.

Results tabulated.—Dried at 100° C.

	I.	II.
Sulphate of baryta - -	98·52	98·40
Silica - - -	0·86	
Alumina - -	0·20	
Peroxide of iron -	trace.	
	99·58	

The white powder occurring with the crystals was also found to consist mainly of sulphate of baryta, but as it was difficult to free it entirely from small particles of the ironstone matrix, the constituents of the ore made their appearance in the course of the analysis more prominently than in the case of the crystals.

LXXXIV.—Pennystone, Donnington Wood, Shropshire.

(By J. Spiller.)

(No. 174 of the Illustrated Catalogue.)

Description.—Clay ironstone, similar in the characters of hardness, colour, and fracture to No. 173. Uniform throughout, with the exception of an exceedingly thin film of lime or iron spar.

Analysis by Method No. III.

Water, hygroscopic and combined:—	grs.
I. 22·615 grs. of ore lost of water at 100° C. - -	0·105
and gave of water on heating to redness - -	0·38
Water total amount:—	
II. 19·105 grs. of ore gave of water at a red heat - -	0·395
By the action of hydrochloric acid:—	
21·4 grs. of ore gave of—	
Insoluble residue (ignited) - - - - -	4·22
Peroxide of iron (containing 0·025 grs. of silica) -	9·19
Manganoso-manganic oxide (Mn_3O_4) - - -	0·30
Alumina - - - - -	trace.
Sulphate of lime - - - - -	1·32
Pyrophosphate of magnesia - - - -	2·785
The insoluble residue (ignited) from 14·9 grs. of ore gave of—	
Silica - - - - - - -	1·855
Alumina - - - - - -	0·83
Peroxide of iron - - - -	0·125
Oxalate of lime - - - - -	trace.
Pyrophosphate of magnesia - - -	0·03
21·01 grs. of ore gave of—	
Organic matter - - - - -	0·02
Chloride of potassium - - - -	0·285

This latter converted into the platinum double salt gave of—	grs.
Chloride of platinum and potassium - - -	0·915
Phosphoric and sulphuric acids, and bisulphide of iron :—	
94·26 grs. of ore gave of—	
Pyrophosphate of magnesia - - -	0·32
71·72 grs. of ore gave of—	
Sulphate of baryta (from sulphates) - - -	0·12
Sulphate of baryta (from bisulphide of iron) -	1·03
I. 17·285 grs. of ore gave of carbonic acid - - -	5·15
II. 18·585 grs. of ore gave of carbonic acid - - -	5·54
Determinations repeated :—	
14·9 grs. of ore gave of—	
Insoluble residue (ignited) - - - - -	2·895
Peroxide of iron (containing 0·035 grs. of silica) -	6·405
Manganoso-manganic oxide ($Mn_3 O_4$) - -	0·185
Carbonate of lime - - - - - -	0·70
(Above converted into sulphate of lime) -	0·955
Pyrophosphate of magnesia - - - -	3·21
The amount of phosphoric acid precipitated with the alumina was also determined in this portion of ore—	
Pyrophosphate of magnesia - - - - -	0·06

Results tabulated.

	I.	II.
Protoxide of iron - -	38·55	38·49
Protoxide of manganese - -	1·31	1·15
Alumina - - -	trace.	
Lime - - - - -	2·54	2·63
Magnesia - - -	4·65	4·82
Carbonic acid - - -	29·80	29·81
Phosphoric acid - -	0·25	0·22
Silica, soluble in hydrochloric acid	0·12	0·22
Sulphuric acid - - -	0·06	
Bisulphide of iron - -	0·37	
Water, hygroscopic - -	0·46	2·07
„ combined - -	1·68	
Organic matter - - -	0·10	
Ignited insoluble residue -	19·48	19·22
	99·37	

Ignited Insoluble Residue.

Silica - - - - -	12·45
Alumina - - - - -	5·58
Peroxide of iron - - - -	0·60
Lime - - - - - -	trace.
Magnesia - - - -	0·07
Potash - - - - -	0·85
	19·55
Iron, total amount - - -	30·40

A minute trace of a white malleable metal, too small in quantity to identify, was found in 300 grains of the ore.

LXXXV.—Pennystone, Madeley Court, Shropshire.

(By J. Spiller.)

(No. 175 of the Illustrated Catalogue.)

Description.—Clay ironstone, easily scratched by a steel point, but harder than Nos. 173 and 174; colour, dark gray; fracture, conchoidal; structure, compact. The one exhibits thin veins filled with a white pulverulent form of silicate of alumina, in which some crystals of iron pyrites occur.

Analysis by Method No. III.

	grs.
Water, hygroscopic and total amount:—	
I. 23·60 grs. of ore lost of water at 212° C.	0·11
and yielded in addition at a red heat	0·31
II. 22·19 grs. of ore gave of water at a red heat	0·335
By the action of hydrochloric acid:—	
17·42 grs. of ore gave of—	
Insoluble residue (ignited)	2·40
Manganoso-manganic oxide (Mn_3O_4)	0·185
Alumina	0·07
Silica, (precipitated with the peroxide of iron)	0·065
Sulphate of lime	0·695
Pyrophosphate of magnesia	1·66
The insoluble residue (ignited) from 16·91 grs. of ore gave by analysis—	
Silica	1·31
Alumina	1·785
Peroxide of iron	0·14
Sulphate of lime	0·055
Pyrophosphate of magnesia	0·04
27·05 grs. of ore gave of—	
Sulphate of baryta (from sulphates)	0·05
Organic matter	0·115
Chloride of potassium	1·14
Phosphoric acid and bisulphide of iron:—	
97·25 grs. of ore gave of pyrophosphate of magnesia	0·44
79·815 grs. of ore gave of sulphate of baryta	0·415
Carbonic acid:—	
I. 25·795 grs. of ore gave of carbonic acid	8·26
II. 35·13 grs. ,, ,,	11·18

Iron, by standard solution of bichromate of potash:—

Standard: 1 gr. of iron = 9·03 cub. cent. of solution.

Iron, total amount (soluble in hydrochloric acid):—

	Weight of ore.	Cub. cent. of solution.	Per cent. iron.
I.	7·99	24·8	34·37
II.	8·75	27·0	34·17

A very small quantity of iron existed in the state of peroxide.

Results tabulated.

Protoxide of iron	44·19
Protoxide of manganese	0·99
Alumina	0·41
Lime	1·63
Magnesia	3·40

Carbonic acid	32·02
Phosphoric acid	0·29
Silica, soluble in hydrochloric acid	0·37
Sulphuric acid	0·06
Bisulphide of iron	0·43
Water, hygroscopic	0·45
Water, in combination	1·31
Organic matter	0·42
Ignited insoluble residue	13·50
	99·47

Ignited Insoluble Residue.

Silica	7·75
Alumina	4·64
Peroxide of iron	0·55
Lime	0·14
Magnesia	0·08
Potash	0·33
	13·49
Iron, total amount	34·75

None of the metals precipitable by sulphuretted hydrogen from the hydrochloric-acid solution, were detected in 445 grains of the ore.

LXXXVI.—Crawstone, Madeley Wood, Shropshire.

(By J. Spiller.)

(No. 176 of the Illustrated Catalogue.)

Description.—Clay ironstone, same degree of hardness as No. 175; colour, dark gray; fracture, conchoidal; structure, minutely crystalline. The ore is traversed by veins of white lime spar, containing a small quantity of carbonate of iron.

Analysis by Method No III.

	grs.
Water, hygroscopic:—	
47·33 grs. of ore lost of water at 100° C.	0·09
Water, total amount:—	
31·42 grs. of ore yielded of water at a red heat	0·23
By the action of hydrochloric acid:—	
17·345 grs. of ore gave of—	
Insoluble residue (ignited)	1·665
Manganoso-manganic oxide (Mn_3O_4)	0·09
Alumina	0·075
Carbonate of lime	0·665
(Above converted into sulphate of lime	0·90)
Pyrophosphate of magnesia	0·205

The insoluble residue (ignited) gave by analysis :—

	grs.
Silica	1·185
Alumina	0·42
Peroxide of iron	0·075
Oxalate of lime, Ammonio-phosphate of magnesia	traces.

41·67 grs. of ore gave of—

Organic matter	0·28
Chloride of potassium	0·11

Phosphoric and sulphuric acids, and bisulphide of iron :—

46·20 grs. of ore gave of—

Sulphate of baryta (from sulphates)	none.
Sulphate of baryta (from bisulphide of iron)	0·03
Pyrophosphate of magnesia	0·165

15·49 grs. of ore gave of carbonic acid - - 5·16

Iron, by standard solution of bichromate of potash :—

Standard : 1 gr. of iron = 8·45 cub. cent. of solution.

Iron, total amount (soluble in hydrochloric acid) :—

	Weight of ore.	Cub. cent. of solution.	Per cent. iron.
I.	9·17	31·0	40·02
II.	9·015	30·4	39·93

No appreciable amount of peroxide of iron existed in the hydrochloric-acid solution.

Results tabulated.

Protoxide of iron	51·45
Protoxide of manganese	0·54
Alumina	0·43
Lime	2·13
Magnesia	0·42
Carbonic acid	33·31
Phosphoric acid	0·23
Bisulphide of iron	0·02
Water, hygroscopic	0·19
Water, in combination	0·54
Organic matter	0·67
Ignited insoluble residue	9·60
	99·53

Ignited Insoluble Residue.

Silica	6·83
Alumina	2·42
Peroxide of iron	0·43
Lime, Magnesia	traces.
Potash	0·16
	9·84

Iron, total amount - - 40·27

A trace of lead was present in the ore in the form of galena.

Iron Ores of North Staffordshire.

General Description. (By Warington Smyth, M.A., F.R.S.)

The Coal-fields of North Staffordshire are situated in a tract of hilly country, intermediate between the higher lands of the Derbyshire Limestone region and the low ground of Stafford, Crewe, and Northwich. They occupy, in all, a breadth of about 16 miles, by a length, where chiefly developed, of about 15 miles; and although originally continuous, are now divided by denudation into three distinct portions separated by barriers of the inferior "Carboniferous" rocks, viz., the Millstone Grit, and accompanying shales. These three parts are, 1st. The great and remarkable coal-field of the Potteries; 2nd. The narrow basin of Wetley and Shafferlong; and, 3rd, The Cheadle and Ipstones coal-field.

The Coal-Field of the Potteries.

In the form of a triangle, the sharp apex of which lies near Congleton, the Coal-measures of this important field expand on the south to a width of nearly 10 miles, as measured across from Longton on the east by Newcastle-under-Lyne and Apedale to the the western boundary. On the north and east they are bounded by the rise of the lower strata which generally form conspicuous hills of hard grit-stone, on the west by the overlying Permian beds and New Red Sandstone, and on the south by the same upper rocks in a very irregular outline, caused by the interference of faults or dislocations.

Whilst, therefore, on the sides first mentioned the beds of coal and ironstone arrive at lines where they are abruptly cut off, by their outcrop or basset, and the field contains for a considerable breadth along these borders only the lower beds, on the west and south there is no doubt about the prolongation of the Carboniferous series far beyond where it is visible at the surface; and although the more valuable seams are overlaid by a great thickness of upper measures, consisting chiefly of red clays, and then by a very variable and uncertain thickness of the Permian or New Red strata, some of the upper ones may probably at a future day be proved to lie within a workable depth.

The actual area, within which the Coal-measures are exposed at the surface, may be estimated at about 70 square miles; but along the central portions of this tract the thickness of the measures is far more considerable than that of any of our English coal-fields, excepting that of Lancashire.

It appears probable that coal and ironstone were worked in North Staffordshire in very remote times, chiefly in consequence

of the numerous outcrops which enabled them to be attacked by the simple process of adits or foot-rails and shallow pits.

As early as, if not before, the year 1500, coarse pottery was manufactured in the neighbourhood of Burslem, where great facilities were offered by the superficial position of beds of clay belonging to the Upper Coal-measures, and by the outcropping of several of the upper seams of coal. We learn from Dr. Plot that in the seventeenth century, this branch of industry had attained considerable importance, but it was after this time that the district began to take its position as the great centre of the British ceramic art. The Messrs. Elers of Nürnberg in 1690 established the manufacture of imitations of the ware of China and Japan; and about the middle of the last century an extraordinary impetus was given to the trade by the ingenuity, perseverance, and taste of the celebrated Wedgwood.* Even before his time raw material from other districts, especially the Dorset or Poole clay, was largely imported; but afterwards, about 1777, the Cornish China-clay (Kaolin) and China-stone came into use, and led to the introduction of new wares and to that rapid extension of the trade which have rendered the district not only the great source of supply of our British requirements, but have given rise to an enormous exportation to foreign countries. The works of Burslem and Etruria have gradually spread along the trough of the Upper Coal-measures until they have formed, with about 150 factories, and the dwellings of the large population (estimated at 60,000) more or less engaged in them, an almost continuous town of some nine miles in length, including, Longton, Lane End, Stoke, Shelton, Hanley, Burslem, Tunstall, Golden Hill, and Kidsgrove. At some of these are ironworks intermingled with the potteries, and the whole range is intersected by the almost parallel great road running from Longton to Lawton, the grand trunk canal, and the line of the North Staffordshire railway. The two latter pass through the north-western outcrop of the measures in the Hare Castle tunnels, giving an excellent section of the majority of the workable seams.

The statements which have been made of the great antiquity of some of the coal workings are not reliable. The methods adopted in the 17th century, of which we have distinct records, were evidently applicable to but limited operations, for the collieries had to be cleared of water either by an adit or *sough*, traces of several of which remain, or horse gins were employed either to wind the water in barrels, or to pump it by means of a chain fitted with leather suckers, and the quantity of coal raised would appear to have been but small, owing to wood being still largely employed for domestic purposes, and charcoal being used in the smelting of iron.

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* See for further details the Catalogue of Specimens of British Pottery in the Museum of Practical Geology, by Sir H. de la Beche and Mr. Reeks, 1855.

The employment of the argillaceous carbonates of this district for the smelting of iron dates from an early period. Dr. Plot, professor of Chemistry at Oxford, writing in 1686, describes several of the measures, and by his reference to their being interfered with by sand and clay, proves that they were worked only at small depth, near the basset or outcrop :—

"In Tunstall field, in the Royalty of the Rt. Honble. Digby Lord Gerard, in diging for *Iron-stone,* they meet first with a small *bass,* then a strong *bass,* then a sort of stone called from its colour *blew-cap,* good for nothing ; and after that the *Iron-stone* of a darkish blew colour, which ordinarily lyes here not above two foot in thickness. On *Mear-heath* they observe in digging for *Iron-stone,* that if they meet with roches, sand, gravel, and clay, that the *head* of the *mine* is quickly eaten out ; especially the last, which so keeps downe the head that it comes to nothing presently, all which they count bad, the works being thinner and more chargeable to dig : but if they meet with *Mine-earth* (as they call it), which is white, then they promise themselves good mines both of *Iron-stone* and *coale,* which as at most other places, lye here together, the *stone* above the *coale,* between four fingers and a foot thick, having *bass* above and below it, in which sometimes also they meet an *Iron-ore* they call *ballstones,* distinct from the *vein* ; and then indeed 'tis thicker ; this, where the *Iron-stone* and *coal* lye together, they call the *deep mine,* which is not the best, the *chalky mine,* and the *little mine* being preferred before it ; yet they are all work't by Mr. Foley, of Longdon, a village hard by."

Dr. Plot states, also, how the quality of the iron produced varies with the character of the ore. He describes the iron smelted from the *Cannock* or *cannot* stone of Dudley as *yellow-share* or *redshare* :—"The second sort of iron they stile *coldshear,* which " though it will not break when red hot, yet in *hot heat* or *cold* " the biggest bar of it may be broken with a small blow upon an " anvil, if it be perfect *cold sheare iron ;* the *ore* for this iron " they have at *Cheslin-hay, Redstreet,* and *Apedale,* the worst " and leanest being that from *Cheslin-hay,* the next from *Red-* " *street,* being a red stone, and the best of the three from *Apedale,* " being of a blewish colour, and called *Boylom ;* yet these three " are commonly mixt together, and sometimes with other *stones* " to make them better or worse."

At this period the ore was smelted with charcoal, and from 2 to 3 tons in 24 hours obtained from a furnace, a great improvement, it was held, over the methods of our ancestors, who made iron in *footblasts* or *blomeries,* " by men treading the bellows, by " which way they could make but one little lump or *bloom* of " iron in a day, not 100 weight, leaving as much iron in the *slag* " as they got out."*

The extension of the iron manufacture, notwithstanding the marvellous change of the scale of operations, has been less considerable than we should be led to expect from the great capabilities of this coal-field. The iron smelting furnaces have been established in several different situations as regards the portion of

* Natural History of Staffordshire, by Robert Plot, LL.D. Oxford, 1686.

the measures on which they are placed, but draw, nevertheless, their supplies from nearly the same series of beds over the whole of the field. For a general view we may divide the entire thickness of the strata into four parts, corresponding of course in consequence of the folding and denudation of the mass with particular bands of the surface area :—

1st. UPPER MEASURES, consisting chiefly of red "marls" or clays with a few thin bands of coal, and some grey binds and sandstones in the upper part, containing an ironstone called the *Top red* mine, 18 inches thick, at Silverdale.
Thickness very uncertain, probably about 1,000 feet.

2nd. POTTERY COALS AND IRONSTONE MEASURES, containing 8 to 13 seams of coal of above 2 feet thick, mostly inferior, and suitable only to pottery purposes; and 10 or 12 workable measures of ironstone.
Thickness 1,000 to 1,420 feet down to the Ash or Rowhurst coal.

3rd LOWER THICK MEASURES, containing the chief furnace coals, from the Ash to the Winpenny inclusive, 17 or 18 seams above 2 feet thick. Ironstone scarce or almost absent.
Thickness, 1,400 to 2,400 feet.

4th. LOWEST MEASURES, including thin seams generally known as the Wetley Moor, Biddulph, or "Wild" coals, from 2 to 4 in number.
Thickness, about 800 feet.

This would give a total, down to the upper bed of Millstone Grit, variable in different parts of the field, of from 4,200 to 5,620 feet.

It may be observed that the occurrence of the ironstones in North Staffordshire is strikingly different from that which obtains in South Staffordshire, and in the more distant fields of Derbyshire, and South Wales, in all of which they are comparatively scarce in the upper, and abundant only in the lower part of the measures. I am unable to conclude that this fact is of weight in drawing a parallel between the different portions of these respective formations, since the ironstone measures, in spite of some few exceptions, are generally variable in a great degree within even moderate distances. Especially is this the case with several of the uppermost of their strata, which assume the character of *black-band*, and which, between the east and west sides of the Potteries coal-field, come in or go out with their whole thickness. As a rule I believe that here, as in all our coal-fields, the seams of coal are far more persistent and equable than any of the other beds with which they are associated.

During the examination of this district for the construction of the map 72 N.W. of the Geological Survey,* I was favoured

* The geology of this map is illustrated by longitudinal sections, Sheets 42 and 54, with explanations by Mr. E. Hull. A map of the coal-field on a larger scale has been published by Mr. Wm. Cope, of Hanley.

by the kindness of several gentlemen interested in the ironworks and collieries with detailed sections of the strata compiled with a great degree of care; and as very little has hitherto been published upon a coal-field no less interesting to the scientific inquirer than to the man of commerce, it may be a useful contribution to knowledge to append the results of the sinkings completed on the east and west and in the central part of the area.

For the first of these, a series of shaft sinkings in the south-east of the field, I am indebted to Arthur Sparrow, Esq., proprietor of the ironworks of Lane End. They exhibit the great thickness of 2,374 feet proved within the boundaries of the estate, the strata below that depth being appended from other sources.

SECTION of COAL-MEASURES at LANE END, in the NORTH STAFFORDSHIRE COAL-FIELD.

In deep of the estates at *Cornish Engine Pit.*	YDS.	FT.	IN.	Total Depth. YDS.	FT.	IN.
Total depth to *Gutter Coal,* measures chiefly fire-clays	50	0	0			
Gutter COAL*	0	2	6			
From Gutter Coal to Red Shag Coal, measures fire-clays and clunch	64	0	6			
				115	0	0
SECTION OF OLDFIELD ASH PITS.†						
From surface to sand clay	5	0	0			
Sand	1	2	0			
White marl	8	2	0			
Strong marl mixed with balls of sand rock	4	0	0			
White marl mixed with balls of *ironstone*	19	1	0			
Red Shag COAL	0	2	0			
Strong marl mixed with beds of peldrin, 5 and 6 inches thick	14	2	0			
Red marl or fire-clay	2	0	0			
Limestone ‡ (fresh-water?)	0	2	0			
White marl	5	2	0			
Red marl or fire-clay	4	0	0			
Bassymine Ironstone § (Anal. xc.)	1	1	0			
Bassymine COAL	0	2	4			
Shaley marl	1	1	0			
Do. stronger	8	0	0			
COAL	0	1	0			
Bass	1	0	0			
COAL	0	0	6			
Clunch binds	5	0	6			
Brown marl	0	2	0			
Peacock COAL	1	0	2			
Shaley marl	1	1	0			
Strong clunch	9	2	0			
Rock	8	0	0			
Black shaley clunch mixed with *ironstone*	8	0	0			
Bass	0	2	0			
Spencroft COAL‖	1	1	0			
Dark shaley marl	0	2	0			

* This coal is so called from its having been cut by a sough or gutter.

† These pits were sunk in 1851–2. The measures lie at an inclination of 6 to 10 inches in the yard.

‡ This limestone contains *Spirorbis* (*Microconchus*) *carbonarius.*

§ The only carbonaceous ironstone in this part of the field; the upper ones occurring farther north and west.

‖ This seam has from its inferior character not been worked in this estate.

		Yds.	Ft.	In.	Total Depth. Yds.	Ft.	In.
Small Coal		0	2	0			
Marl		0	2	0			
Coal		0	2	0			
Marl		0	2	0			
Coal		0	2	0			
Strong clunch		3	0	0			
„ rock		2	0	0			
„ clunch		4	0	0			
Great Row Coal*		2	2	0			
Strong clunch		10	0	0			
Peldrin		0	1	0			
Bass		1	1	1			
Cannel Row Coal†		1	2	0			
Strong clunch		11	2	0			
Rock		2	0	0			
Strong clunch mixed with beds of rock		10	0	0			
Woods Mine Measures.	Bass	1	0	0			
	Ironstone	0	0	3			
	Bass	0	2	0			
	Ironstone	0	0	2			
	Bass	0	2	0			
	Ironstone	0	0	2			
	Bass	0	2	0			
	Ironstone	0	0	2			
Bass		0	1	9			
Coal		0	1	3			
Bat		0	1	6			
Coal		0	1	0			
Strong clunch		4	1	0			
Deep Mine Measures. (Analysis XCII.)	Top *Ironstone*‡	0	0	6			
	Bass	0	1	6			
	2nd *Ironstone*	0	0	3			
	Bass	0	1	6			
	3rd *Ironstone*	0	0	2			
	Bass	0	1	3			
	4th *Ironstone*	0	0	4			
Coal§		1	0	6			
Strong rock binds mixed with clunch		13	1	0			
Black bass mixed with thin beds of *ironstone*		3	1	0			
Chalky Mine Measures. (Analysis XCIV.)	1st *Ironstone*‖	0	0	3			
	Bass	0	2	3			
	2nd *Ironstone*	0	0	2			
	Bass	0	1	9			
	3rd *Ironstone*	0	0	7			
Coal		0	1	0			
Clunch		8	0	0			
Rock¶ mixed with tar, 10 yards in one pit and 12 in the other		10	0	0			
Rock without tar		3	2	0			
Black bass mixed with balls of *ironstone* in the bottom		4	0	0			
*New Mine Measures.—Ironstone***		0	0	5			
White clod		1	0	0			
Coal		0	1	10			
Dark slumbs		1	2	0			
Strong clunch		3	1	0			
Rock		2	0	0			
Black bass		1	2	0			

* One of the inferior coals, chiefly used for the potteries.
† This seam, containing much sulphur, is not fitted for furnace purposes.
‡ The richest and best ironstone in this part of the field.
§ Of inferior quality.
‖ Mixed with a good deal of "cement stone," poor in iron.
¶ Mineral tar drained for a long time and in large quantity from this sandstone.
** A better stone than the last, but in smaller quantity.

	YDS.	FT.	IN.	Total Depth. YDS.	FT.	IN.
*Hanbury Mine Measures.** { *Ironstone*	0	0	3			
Bass, with cakes of *ironstone*	2	0	0			
COAL	0	0	8			
Strong clunch	4	0	0			
Rock	2	0	0			
Clunch	3	0	0			
Shaley marl	6	1	0			
COAL	0	1	2			
Clunch	3	0	0			
Rock	2	2	0			
Bass, with 4 bands of *ironstone, New Ironstone Measures*	1	1	6			
Clunch	2	0	0			
Knowles rock	7	0	0			
Rock binds	2	0	0			
Bass	4	2	0			
Bay COAL	0	1	8			
Light clunch	0	2	0			
Rock	10	0	0			
Strong clunch, mixed, with rock	5	1	0			
Knowles or *Winghay* COAL (6 inches bat included)	2	1	6			
Black shaley bass	1	1	0			
Strong clunch	5	0	0			
Bass and band of *ironstone,* 4 inches thick	0	1	6			
Rock binds	5	1	0			
Priorsfield bass, mixed with balls of *ironstone*†	9	1	0			
Clunch	6	2	0			
Rock	5	2	0			
Knowles bass and *ironstone,* 5 beds in the lower 9 ft.	10	2	0			
COAL	0	1	8			
Clunch	5	1	0			
Black Mine Bass, containing three beds of *ironstone,* two beds 2 inches each, 1 bed 1 inch thick	1	1	0			
COAL	0	0	9			
Shaley marl	2	0	0			
Ash rock, very strong	37	0	0			
Rider bass, black	1	1	0			
Rider COAL	0	2	3			
Strong clunch	5	1	0			
Stoney rock	1	2	0			
Black bass	0	2	0			
Ash COAL (*Rowhurst*)‡	2	1	0			
Fire-clay	2	0	0			
Stone rock	1	1	0			
Clunch	5	0	0			
	406	0	11			
From Surface to *Red Shag Coal* at CORNISH ENGINE PIT				115	0	0
From *Red Shag Coal* to *Ash Coal,* as per section at OLDFIELD ASH PITS				359	0	11

CALFCROFT PITS SECTION, below *Ash Coal,* which is there 169 yards deep.

	YDS.	FT.	IN.	YDS.	FT.	IN.
Marl	0	2	0			
Basil	0	2	0			
Fire-clay	5	0	0			
Rock	12	0	0			
Fire-clay	14	0	0			
Bass, mixed with stone	0	2	0			
Little Mine COAL (*Tabberners*)	0	2	6			
				33	2	6

* Discovered and worked by Mr. A. Sparrow.
† This and the Knowles ironstone are the leanest in the series.
‡ A good bright furnace coal for ironworks.

	YDS.	FT.	IN.	Total Depth. YDS.	FT.	IN.
Distance from *Little Mine Coal* to *Gin Mine Coal* at Ashwell's Pits				19	0	0
SECTION OF MEAR HAY PITS, AT MILLFIELD GATE.						
Soil and clay	1	1	0			
Shaley marl and Gin mine	9	0	0			
Gin Mine or Golden Twist COAL	0	2	0			
White sandy rock	18	0	0			
Black bass	6	0	0			
COAL	0	0	9			
Marl slumbs	1	1	0			
Strong marl, mixed, with beds of rock	5	0	0			
White rock	13	0	0			
Fire-clay	6	0	0			
Black bass	5	0	0			
White rock	10	0	0			
Fireclay or marl	3	0	0			
Ironstone Measures. *Stone*	0	0	4			
Bass	0	2	0			
Stone	0	0	4			
Bass	0	2	0			
Stone	0	0	4			
Bass	2	1	0			
Fireclay, mixed with beds of *ironstone*	6	0	0			
Doctor's Mine COAL	0	1	4			
Rock binds	5	0	0			
Fireclay	1	2	0			
Sandstone rock	13	0	0			
Clunch	24	0	0			
Rock binds	15	0	0			
Clunch	10	0	0			
Bass	0	2	3			
Black shaley clunch	7	0	0			
Moss COAL* (*Mossfield*)	1	2	0			
White clunch	6	0	0			
COAL	0	1	8			
Clunch	9	2	0			
Dark slum	1	2	0			
Rock binds	8	2	0			
Rock	44	1	6			
Marl	2	1	0			
Black bass	2	1	0			
Yard COAL†	1	2	0			
Stony clunch, mixed with beds of rock	3	0	0			
Dark clunch	7	0	0			
COAL	0	1	6			
Dark marl	0	2	0			
Rock binds	3	1	0			
Dark clod	0	2	0			
Rock binds	10	0	0			
Grey bass	4	0	0			
Birches COAL‡ (*Old Whitfield* of Norton)	1	2	0			
Depth of Mear Hay Pits	275	1	0			
Distance from the *Gin Mine coal* to the *Birches*				261	4	0
Total measures proved by Messrs. Sparrow				791	1	5

* This is a first-rate house fire coal, very swift burning, and little or no ash; very bituminous.

† This is the principal furnace coal, it is hard and free from sulphur.

‡ This is a good potter's coal, slow burning, but a bad furnace coal; sulphurous.

Section at Stirrup and Pye's, Adderley Green Colliery.	Yds.	Ft.	In.	Total Depth. Yds.	Ft.	In.
*Birches Coal to Ten-foot**	90	0	0			
Ten-foot Coal	1	0	0			
Ditto to Bowling Alley	36	0	0			
Bowling Alley Coal†	1	1	0			
Ditto to Hollylane	24	0	0			
Hollylane Coal‡	0	2	3			
Parting	0	0	3			
Indifferent Coal	0	3	0			
Ditto to Sparrow Butts	20	0	0			
Sparrow Butts Coal	1	1	0			
Ditto to Stinking coal§	15	0	0			
Stinking Coal, a 6-inch parting in the middle	1	1	0			
Ditto to ironstone coal, including two bands of *ironstone* about 6 inches thick each, and which lie 2 feet above Ironstone coal	59	0	0			
Ironstone Coal (*Flatt's mine*)	0	2	2			
Ditto to Banbury coal	36	0	0			
Frogs row or *Banbury* Coal	1	1	0			
Ditto to Cocksheads, including two or three bands of good *ironstone*, which lie in about 4 feet above the Cocksheads coal	45	0	0			
Cocksheads Coal (probably one of the *Nabbs coals* at Kidsgrove)	2	2	0			
	336	1	8			
				1,128	0	1
From the Cocksheads to the Sudden coal about	80	0	0			
Sudden Coal	1	0	0			
				1,209	0	1

This is the lowest coal proved in the south-east portion of the N. S. coal-field, and has only been gotten in one place; viz., at Bucknall, by a man named Fisher, some years ago.

Below this, however, near Norton, several other seams have been worked, and the following is an approximate section:—

	Yds.	Ft.	In.	Yds.	Ft.	In.
From the Cocksheads Coal Measures, with *Limekiln* or *Sudden* Coal	140	0	0			
Bullhurst Coal	0	4	0			
Measures	20	0	0			
Winpenny Coal	0	3	0			
Measures, with uncertain Coal seams	200	0	0			
Four-foot Coal, Wetley	0	3	6			
Measures	40	0	0			
Two-foot Coal	0	2	0			
From the Cocksheads coal to Two-foot	404	0	6			
Total thickness of coal-measures				1,532	0	7
Total number of seams coal 47; whose aggregate thickness is				46	2	8

With respect to the two lowest coals named in the above section, they are not obtained in the same sinkings with any of the upper seams, and are of small technical value. But in a geological point of view they are of high interest, as exhibiting

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* At Norton there occurs at 60 yards above the Ten-foot a seam called the *Bellringer*, 3 feet 3 inches thick.

† Inferior quality.

‡ Good house fire coal.

§ This is a fair furnace coal.

marine fossils in their accompanying shales, which enable us to identify, or at the least to compare them, with the lower seams of the remaining fragments of the North Staffordshire coal-field, to be presently noticed, and with those of Lancashire, North Wales, and Derbyshire.

Above Bucknall, on the rough ground of Wetley Moor, we find thus—

The "Four-foot" COAL, 3 feet thick, including 4 or 5 inches of clod or clay in the middle; the roof shale contains *Goniatites* in abundance; below this occur—

Marls or binds, 15 to 20 yards.

Reddish rock, grit partly very rough; 8 yards.

Black metals and rock bind, 11 yards.

"Two-foot" COAL, 20 inches thick, having a rough bind roof, in which I found no fossils.

The "Four-foot" is of poor quality; the 20-inch very good for smith's purposes.

Farther north, at the foot of the high ridge called Baddeley Edge, the "Four-foot" was working in 1852–4, from a pit 23 yards deep, lying upon shales of a chocolate colour, dipping 60° west, and having a roof of grey shale containing *Lingula.*

At Knipersley the shales which lie between the "Winpenny" and the "Four-foot" are exposed on the eastern side of the reservoir, and exhibit an abundance of *Aviculo-pecten papyraceus.*

In passing from the Lane End works to the extensive smelting furnaces, forges, and collieries of Earl Granville and Co. at Shelton, we find a considerable change to have taken place in many of the seams, and especially in the development of certain of the "measures" of ironstone. It is, in fact, a little difficult to identify some of the beds, known as they often are, after a short interval, by different names. But the most variable of these measures are the more or less carbonaceous ironstones which occur above the Bassy Mine Coal, and which are at the same time of great value to the smelter, and highly interesting from their fossil contents to the geologist. At a small depth, however, below this latter lies a seam of coal, called from its iridescence the "Peacock," which appears to run pretty regularly throughout the coal-field, and which may therefore conveniently serve as a datum line for the comparison of the overlying strata. This seam, with its bright colours, attracted the attention of our forefathers, and Dr. Plot, in endeavouring to draw a just comparison between it and the other beds, states that "the Peacock coal is "no more capable of politure than the common coal, yet is "more gay to the sight than if it were, it most vividly repre-"senting all the colours of the most glorious feathers in a pea-"cock's trayne; and that not emphatically, like the colours in "a glass prisme, or of variable silk, which are evanid at least, "if not fantastical; but solidly and genuinly, the colours "remaining fixt in all manner of obversions of the coal, though "not so vivid when turned from the light."

In the central part of the field the sections given by Lord Granville's pits commence, near Etruria Hall, in the lower part of the red clays, which I have above described as forming the upper division of the carboniferous series. To Mr. John Lancaster I am indebted for the results of the sinking of three pits, which will form part of the following section, and to Mr. Hedley, now Her Majesty's Inspector of Coal Mines for Derbyshire, for details in the adjoining estate of Sneyd Green, in which particular attention has been bestowed on the ironstones.

Section of Coal-measures at Shelton, Staffordshire.

No. 9, Gutter Pit, Cobridge.

	YDS.	FT.	IN.
Pit Bank	2	1	0
Yellow clay	0	2	0
Red marl	2	0	0
White and red marl	2	2	0
Blue bind	4	2	0
Ditto with beds of rock	3	0	0
Blue bind	2	2	0
Coal	0	0	3
Dark warrant	0	1	6
Light fire-clay	1	1	6
Blue bind	0	2	0
Rock in beds	2	0	0
Blue metal	3	1	7
Black bass	0	0	6
Warrant	0	0	3
Black bass	0	1	6
Red Shag Ironstone (Anal. LXXXVII.)	0	1	4
Coal	0	1	0
Marl	16	1	0
Coal	0	2	9
Grey marl	4	2	8
Strong marl with stone balls	14	2	0
Rock	2	0	0
Grey marl	2	1	2
Strong rock	0	2	6
Marl with rock binds	2	0	0
Gutter Stone (Anal. LXXXVIII.)	0	2	3
Gutter or *Fenton Low* Coal	0	2	3
	73	1	0

Ladies Well Pit, Shelton, 12 yds. 2 ft. 3 in. to bottom of *Gutter Coal.*

	YDS.	FT.	IN.
Brown metal	10	0	0
Light metal	16	0	0
Bass and Coal	0	1	0
Light earth	0	0	9
Coal	0	1	8
Light warrant	1	0	0
Coal	1	0	0
Warrant	3	0	0
Coal	0	1	8
Strong warrant	6	0	0
Strong metal with bands of rock	15	0	8
Little Coal	0	0	8
Dark warrant	4	1	0
Little rock	0	2	0
Light metal	1	1	0
Black bass	0	0	7

	YDS.	FT.	IN.
COAL	0	1	7
CANNEL	0	1	4
COAL	0	0	7
Light warrant	1	1	0
Strong light rock	2	0	6
Strong light metal	1	2	0
Dark metal	1	0	0
Strong light metal with bands of stone	3	2	0
Dark metal	1	2	0
Light rock	1	0	0
Hard stone	1	1	0
Dark metal with bands of stone	6	1	0
Black bass	2	0	0
*Red Mine Ironstone** (Anal. xc.)	1	0	0
Bassy Mine COAL	0	2	3
Brown warrant	5	2	3
Black bass	0	0	6
COAL (*Little Row* of Fenton)	0	1	8
Dark warrant	1	1	0
Rock binds	2	0	0
Light rock	3	0	0
Rock binds	4	0	9
Light metal with stone bands	2	0	0
Peacock COAL	1	2	4
Light warrant	2	0	6
Dark metal	1	2	2
Light metal	1	0	0
Rick and metal binds	6	1	6
Dark metal	0	2	0
Spencroft COAL	1	1	0

SECTION CONTINUED FROM SNEYD GREEN COLLIERY.

		YDS.	FT.	IN.
Inferior fireclay		15	1	0
Light coloured shales		6	0	0
Gubbin Stone (16 ins. of ironstone)	Ironstone	0	0	6
	Light shale	0	1	3
	Ironstone	0	0	1
	Shale	0	0	2
	Ironstone	0	0	2
	Shale	0	0	2
	Ironstone	0	0	1
	Shale	0	0	6
	Ironstone	0	0	6
Soft fireclay		0	0	8
Inferior fireclay		10	2	0
Thin irregular bands of *Ironstone*† in 9 ft. of inferior fireclay		3	0	0
Bed of *Ironstone*		0	0	4
Inferior fireclay		1	0	6
Great Row COAL		2	2	0
Inferior fireclay, interspersed with hard beds of listy rock		18	0	0
Dark shales		5	1	0
Cannel Row	COAL, inferior	0	1	5
	Carbonaceous *ironstone*	0	0	10
	COAL, with two thin bands of cannel near the top	1	1	6
	Fireclay	0	0	9
	COAL, inferior	0	1	6
Fireclay		0	1	6
Black shale		1	1	6
Inferior fireclay		9	1	0
Ironstone of irregular thickness ‡		0	0	7
Light shale		0	1	3

* Often called the *Bassy* Mine.
† Not at present worked.
‡ Not hitherto worked.

	YDS.	FT.	IN.
Ironstone	0	0	5
Soft fireclay	0	0	6
Inferior fireclay, with small, lean beds of *ironstone*	3	1	0
Dark shale	1	2	0
Lean *ironstone, Wood mine*	0	0	7
COAL	0	2	0
Dark shales	4	2	6
Pennystone (Anal. XCII.) { Three to four bands of flattened nodules in a matrix of light shale band of leanstone *croisels*, 3 in. *Main band ironstone* 10 in. }	1	1	0
Soft fireclay	0	0	8
Hard inferior fireclay	2	0	4
Deep mine Ironstone (Anal. XCIII.)			
Dark shale, with *ironstone* in three or four bands	1	0	8
COAL, *Deep mine*. { Top, very inferior	0	1	4
COAL, *Deep mine*. { Bottom, good common coal	0	1	4
Strata of shale and inferior fireclay	25	0	0
Chalky ironstone (Anal. XCIV.), several bands, not proved at Sneyd Green, with strata of shale*	4	0	0
Two-foot mine. { Carbonaceous *stone*	0	1	0
Two-foot mine. { Regular band, good argillaceous *stone*†	0	0	5
COAL	0	2	0
Strata, chiefly of fireclay, with a few thin bands of *Ironstone*	85	0	0
Thin COAL	0	2	0
Fireclay	3	0	0
Winghay or *Knowles* COAL‡	1	1	6

SECTION CONTINUED FROM FAR GREEN PIT, HANLEY, in which the *Winghay* is 43 yds. 0 ft. 1 in. deep.

	YDS.	FT.	IN.
Black metal	0	2	2
Grey metal	2	1	0
Black bass	0	2	6
Alternations of grey and black shales	30	1	8
Rock	2	2	0
Grey metal	3	2	10
Black metal	8	2	0
Billy COAL§	0	1	6
Grey and black metals	41	2	5
COAL	0	1	9
Rock	2	2	8
Strong grey metal	10	0	0
COAL	0	2	0
Black metal	16	0	6
Ash or *Rowhurst* COAL { *Rider* Coal	1	2	0
Dark marl	0	1	2
Main Coal‖	2	1	0
Dark marl	0	1	0
Coal }	1	0	0
Grey marl with beds of *ironstone*	3	1	6
Blue metal	2	2	9
Black metal	1	2	0
Grey metal	6	1	0
Grey rock	4	0	0
COAL	0	1	6
Black dirt	0	2	0
COAL	0	0	6
Black dirt	0	2	0
Dark marl	3	0	0
Black bass with *ironstone* balls¶ (*Burnwood*) about 12 in. thick in all	2	0	0

* At Ladies Well Pit 21 in. of ironstone in 5 ft. 5 in. of ground.
† This has been worked at the outcrop.
‡ Second-rate potter's coal, equal to the Peacock and Spencroft.
§ Above this coal at Sneyd Green is a 9-inch ironstone.
‖ The best potter's coal.
¶ Probably the same as the *New Mine* at Kidsgrove.

	YDS.	FT.	IN.
Burnwood COAL	1	2	2
Black dirt	0	0	6
Fireclay	3	0	0
Grey metal	4	1	2
Rock	0	2	6
Black metal	0	1	8
Grey metal	2	1	8
Dark metal	7	0	0
Black bass	1	2	6
Twist CANNEL	0	2	4
Twist COAL	0	1	8
Grey metal	11	0	0
Black bass	8	2	0
COAL	0	1	6
Dark marl	2	2	8
Grey metal	4	1	7
Strong rock	1	0	0
Black metal	2	0	9
Grey metal	17	1	0
Black bass	3	1	0
COAL	0	0	3
Grey metal	0	2	9
Strong red rock, with water	17	0	0
Black metal	2	0	0
Strong grey rock	10	2	0
Black metal	2	1	3
Black bass	2	2	6
Black metal	1	0	3
Ditto, with balls of *Ironstone*	2	0	0
COAL	0	1	0
Loamy grey metal (under-clay)	6	1	3
Grey metal	11	0	0
Blue metal	7	1	0
Black bass	1	0	0
Grey rock	5	0	3
Blue metals	7	0	0
Grey metals	4	2	8
COAL	0	0	4
Loamy grey marl (under-clay)	6	1	6
Grey metals	5	0	0
Black basses	7	0	6
Good COAL	0	2	3
Black dirt, parting.			
COAL	1	0	3
Grey metals	13	1	0
Black bass	2	1	0
Blue metal	6	0	0
Black bass	0	2	6
Moss COAL,* sometimes called the *Easling*	1	0	10
Loamy metal (under-clay)	3	0	8
Blue metal	7	1	9
Bassy CANNEL	0	0	9
COAL	0	2	3
Loamy grey metal (under-clay)	2	1	8
Stony ditto, with balls of *Ironstone*	1	2	4
Grey metal	9	0	8
Black bass	1	1	6
COAL	0	2	3
Dark metal	1	2	6
Grey ditto, with balls of *Ironstone*	5	1	1
Strong grey metal	11	0	0
Grey rock	20	1	6
Black bass	5	2	2
Good COAL, *Yard* seam	1	0	6

* Excellent house fire coal.

	YDS.	FT.	IN.
Grey metal	4	0	0
Black bass	0	0	1
Grey metal	2	0	2
COAL } *Ragman*	1	0	10
Dirt parting } *Ragman*	0	0	2
COAL } *Ragman*	0	0	6
Dark metal	4	0	6
COAL	0	2	3
Black dirt parting	0	0	5
COAL	0	0	6
Dark grey metal	4	2	2
Black bass	0	0	4
COAL	0	0	2
Grey metal	1	0	0
Grey rock	12	2	0
Grey metal	1	0	6
Black bass	1	1	6
COAL } *Rough Seven-Foot*	0	1	10½
Dirt parting } *Rough Seven-Foot*	0	0	3½
COAL } *Rough Seven-Foot*	0	2	3
Grey metal (bottom of pit 508 yards deep)	1	0	0

If we form a summary of these sections, taken from the middle of the coal-field, we have :—

	YDS.	FT.	IN.
1st, from the surface to Gutter Coal	73	1	0
2nd, from the Gutter Coal to the Spencroft (Ladies Well Pit)	119	2	11
3rd, from the Spencroft to Winghay (Sneyd Green)	215	2	0
4th, Winghay to Rough 7-foot at bottom of Far Green Pit	465	0	0
	873	2	11

And adding to this an approximate section of the measures seen at Norton, nearly corresponding to that already given for Longton,—

	YDS.	FT.	IN.
5th, lower measures at Norton, from the Old Whitfield, 40 yards above the stony 8-foot, down to the bottom 2-foot Coal	733	0	9
we obtain a total of	1,607	0	8

In the detailed sections we have 28 seams of coal, of 2 feet and upwards in thickness, in the lower part 12, making in all 40 seams of what may be considered a workable thickness.

In all, there are no less than 62 separate beds of coal, with an aggregate thickness of 165 feet.

In order to obtain a view of the variations of the measures throughout the entire field, I append a section of the mines at Silverdale, as supplied to me from the information of the underground manager, Mr. Bostock.

	YDS.	FT.	IN.
Top Red Mine	0	1	6
Clays and thin bands of rock	35	0	0
Black Band (*Bassy* of Apedale) (v. Anal. XC.) irregular 0 to	1	0	0
COAL	0	2	9
Strong marls and a bed of rock	10	0	0
Red Shag Ironstone, 0 ft. to	1	2	0
COAL	0	2	0
Marls and band of rock	14	0	0
Red Mine lower (Anal. LXXXIX), 0 to	1	2	0

	Yds.	Ft.	In.
Coal	0	2	0
Marls, in which the *Bassy Mine* was expected but not found	50	0	0
Peacock Coal	0	2	6
Measures	25	0	0
Spencroft Coal, average	1	2	6
Measures containing a rough sandstone breccia called *Betty Napper*, 2 to 21 ft., under which eight bands of *Ironstone*	19	0	0
Great Row Coal, sometimes in two bands with Cannel	2	2	0
Measures	18	0	0
Cannel or *Little Mine**	2	0	6
Measures	9	0	0
Gubbin Ironstone	0	1	2
Measures	10	0	0
Blue Flats, in bands	0	0	10
Sheath Mine, 0 to 12 ins.	0	1	0
Black Stone, in bands	0	0	10
Coal (*Deep Mine*, in the Pottery)	0	0	6
Measures	14	0	0
Rusty Mine, in bands, 6 in. to	0	0	8
Measures	18	0	0
Chalky Mine, 8 or 10 bands, 2 ft. of *Ironstone* in	6	0	0
Measures	12	0	0
New Mine Stone, 10 in. in	2	0	0
Measures	16	0	0
Winghay Coal	1	2	6
Brown Stone, under, in bands and balls, 20 in. in	3	0	0
Measures	24	0	0
Top Thick Band, in two beds	0	0	8
Middle Thick Band Coal	0	1	3
Ironstone, two bands, 7 ins. in	1	1	0
Bind	14	0	0
Gold Mine Ironstone, 24 ins. in	3	0	0
Measures	25	0	0
Rowhurst Coal, 7 feet, in two bands†	2	1	0
Clunch	3	0	0
Lower Coal (*Bingay*, in Pottery)	1	0	0
Measures	15	0	0
Ironstone	0	0	6
Coal, *Burnwood*‡	0	0	6
Measures	9	0	0
Ironstone, two bands	0	0	6
Coal, *Twist*	1	0	3
Measures, with 12 ft. rock, 5 or 6 yds. above the next	40	0	0
Four-foot Coal (*Moss*, in Pottery)§	1	1	6
Measures	8	0	0
Two-foot Coal	0	1	6
Measures	12	0	0
Single Five-foot Coal (4 ft. at Kidsgrove)‖	1	2	0
Measures	25	0	0
Ragman Coal	1	0	6
Measures	4	0	0
Rough Seven-foot Coal	2	1	0
Measures, 2 ft. of shale at Leycett, 20 yds. of rock at Apedale	10	0	0
Hams Coal, 4 ft. to	1	2	0
Measures	30	0	0
Stoncy Eight-Foot Coal, here only¶	0	1	6
Measures, including 8 yds. of rock at bottom, at Talk-on-the Hill, 20 yds.	60	0	0

* Inferior coal.
† Inferior coal.
‡ Inferior quality.
§ Best house coal.
‖ Fine *Unios* in the roof.
¶ Inferior quality.

	YDS.	FT.	IN.
Ten-foot COAL	2	1	6
Measures	20	0	0
Ironstone, two bands	0	0	6
Top Two-Row COAL*	0	2	3
Measures	10	0	0
Bottom Two-Row COAL*	0	2	3
Measures	10	0	0
Clod COAL, in two bands†	0	2	3
Measures	10	0	0
Bowling Alley COAL‡	0	1	4
Measures, shaly	44	0	0
Rock or strong sandstone	20	0	0
Shale roof	1	0	0
COAL, *Seven-foot Nabbs*§	1	2	6
Measures	7	0	0
Rider COAL	0	0	6
Strong ground	30	0	0
COAL, *Eight-foot Nabbs*‖	1	2	0
Measures, with three little COALS of 15 in. each, 45 ft. apart	65	0	0
COAL, *Bullhurst*, 3 ft. to	2	0	0
Measures	20	0	0
COAL, Winpenny	0	2	2

These distances are taken as sunk through, which, as the strata are very commonly inclined at such an angle as to dip 12 inches in the yard, gives a considerable excess over the true thickness. It is hence interesting with respect to the deposition of the sedimentary matter forming the Coal-measures, to observe that we have here a total thickness from the uppermost of the ironstone measures to the Winpenny coal of 834 yards 0 ft. 2 in.; whilst the total thickness given by the Lane End sections down to the same coal is no less than 1,290 yards 1 ft. 1 in. The Shelton and Norton sections give an approximation to 1,365 yds. 1 ft. 2 in.; and thus it would appear from the Silverdale section, confirmed by those of Apedale (which are only slightly thicker) as given in Smith's "Miner's Guide," that the strata as they pass to the west suffer a great attenuation within a distance of a very few miles.

It will hence be seen, among other conclusions, that it is difficult to draw a parallel between the individual strata of the Potteries Coal-field and those of South Staffordshire, Shropshire, and North Wales, with all of which there is every probability that the Coal-field of North Staffordshire is more or less connected, beneath the great mass of superincumbent red rock which forms the surface of the intermediate land.

The upper ironstones, forming regular strata, and partaking of the character of *black bands*, are in this field so remarkable, from the peculiarity of their occurrence and from their fossil contents, that it may be interesting to compare in the following table the comparative positions of these beds, as determined by the foregoing sections :—

* These two coals are together at Towerhill, in one seam of 9 feet thick.
† Inferior quality.
‡ Increases to 5 feet at Tower Hill.
§ 9 feet at Kidsgrove.
‖ Of good quality.

Comparative View of the Upper Measures above the Peacock Coal.

Silverdale.	Shelton.	Lane End.
	Top of Section.	
	75 ft. 5 in. *Red Shag Stone.*	Top of Section.
Top Red Mine.	137 ft. 7 in. *Gutter* Coal and *Stone.*	152 ft. 6 in. *Gutter* Coal.
107 ft. 9 in. *Blach Band* and Coal.		
32 ft. *Red Shag Stone.*	185 ft. 6 in. Coal and Cannel.	192 ft. 6 in. *Red Shag* Coal.
42 ft. 6 in. *Red Mine* and Coal.		
152 ft. 6 in.	69 ft. 6 in. *Bassy* Coal and *Mine.*	87 ft. *Bassy* Coal and *Mine.*
	62 ft. 6 in.	53 ft. 2 in.
Horizon of the *Peacock* Coal.		

Special Description of the Chief Iron Ores.

(Museum of Practical Geology, Wallcase 55, Shelf 5, 6, 7.)

Red Shag Ironstone (Anal. LXXXVII.)—This bed, at Shelton, lies immediately upon a foot coal, and is 15 to 17 inches thick, exhibiting very numerous laminæ of deposition, which, in the transverse section, give a multitude of brown and black stripes, generally from $\frac{1}{20}$ to $\frac{1}{4}$ of an inch in thickness. It is mostly crammed with small bivalve shells, *Anthracomya*, lying flattened between some of the laminæ. The stone contains so large a proportion of carbonaceous matter, that no coal is required for its calcination. The Red Shags, as well as the other "black bands," have only within a recent period come into use, and from their great abundance and the economy with which they can be calcined, have led to a large exportation to the iron-works of South Staffordshire.

Gutter Ironstone, not observed at Lane End, and somewhat poor at Shelton, is said by some to be the same bed which between Chesterton and the mouth of the Harecastle tunnel

attains the great thickness of 6 feet. At Shelton (Anal. LXXXVIII.) it is, like the above, densely filled with bivalve shells, often following with their laminæ of deposition curved surfaces, and occasionally interspersed with fragmentary fossil remains of plants. When calcined and mingled with some hæmatite it is employed as "puddle-ore."

Red Mine of Silverdale and Apedale (Anal. LXXXIX.) lies upon a seam of coal, and is variable in thickness, averaging frequently 14 inches. This it is which attains so great a thickness near the tunnel mouth, and is, from its position, somewhat difficult to identify with the last. It is generally brown, with black stripes, and contains abundance of bivalves; the same, I believe, with those above noticed.*

Bassy Mine, called "Red Mine" at Shelton (Anal. XC.)—This ironstone, so well developed in the eastern part of the field, has been worked in open-cast along a line of great extent, from Shelton northward, by the back of Burslem and Tunstall, and thence round the curve of the basin to Broadfield. After crossing the line of the tunnel some transverse faults interrupt the measures, and beyond these the names of the beds are so changed that it is difficult to compare them.

In the south-eastern part of the area the Bassy ironstone is 4 feet thick, resting upon a coal-seam, and having, a few feet above it, the singular band of limestone with freshwater shells, which has been compared with a similar bed lying high in the measures in South Shropshire and in Warwickshire, and with the more abundantly developed limestones of Ardwick near Manchester. At Lane End, Mr. Sparrow informs me that it will turn out as much as 5,000 tons to the acre, but that if employed in too large a proportion it deteriorates the quality of the iron, so that it is usual to mix it in the proportion of one-third part. At Shelton it is 30 inches thick, and is calcined in large heaps of as much as 2,000 tons, the stony parts of the Cannel Row seam being used to assist in the calcination. At these works the black-bands, *i.e.* Red Shag and this Red Mine, are employed in about equal proportion with clay mines or ores, chiefly the *Pennystone;* and some little Ulverstone hæmatite or Froghall ore is added.

Its character throughout is that of an even bed, showing numerous lines of deposition, mostly brown, with black stripes, sometimes with thin laminæ of bright coal. Large *Stigmariæ* occur frequently in it, often showing with much distinctness the attachment of the long rootlets to the flattened stems; and some of the laminæ are composed almost exclusively of bivalves (*Anthracomya*), whilst markings of many kinds occur, and abundant specimens of the little *Microconchus* or *Spirorbis carbonarius*. Remains of the fish *Diplodus gibbosus*, and *coprolites* containing portions of them, have been found in this stone at Shelton.

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* *See* also Appendix, on the fossils, p. 292.

Cannel Mine of Apedale (Anal. XCI.)—This is a black, dull, compact, argillaceous ironstone, with a fracture slightly conchoidal, and calc-spar sparingly exhibited on the faces of the joints. Six beds of these nodules, together 12 inches thick, occur in a thickness of 5 ft. 6 in., and it is reputed to yield here about 18 cwt. to the square yard.

Gubbin, occurring some 20 yards below the Spencroft coal, is a dark variable stone, in rows of nodules amounting to 13 or 16 inches, generally much mingled with shale; fossils (*Anthracosia*) scarce. It bears a strong family likeness to the well-known South Staffordshire *Gubbin.*

The *Cannel Row* contains sometimes a stony band, which is a kind of carbonaceous ironstone.

Pennystone, of Shelton (Anals. XCII.) 20 inches of ironstone in three bands, the lowest of which is 10 to 12 inches; a brown, stripy, coarsely grained stone, with occasional laminæ of black shale. It contains broken fossil remains, and occasional crystalline portions of zinc-blende.

Deep Mine (Anal. XCIII.)—At Lane End, decidedly the richest and best ironstone; yields there 10 cwt. per square yard. At Shelton it occurs in three bands of 2, 3, and 4 inches thick respectively. This would appear to occupy the place of the *Sheath Mine* and *Black Stone* on the western side of the field, which together produce at Apedale 17 cwt. to the square yard. The Deep Mine is a blackish grey stone, with smooth surfaces above and below, and a white powder in the cracks. In its shales have been found remains of several genera of fish, especially *Megalicthys, Platysomus, Ctenoptychius, and Diplodus.*

Chalky Mine (Anal. XCIV.)—This at Lane End is much mixed with "cement stone," but yields about 12 cwt. to the square yard. At Shelton it is in four bands, forming together 1 foot thick. It is a somewhat rough, dark stone, with smooth upper and under faces, and containing the occasional admixture in the cracks of a white powder and of zinc-blende.

At Silverdale and Apedale, another measure, the *Rusty Mine,* overlies it, and the Chalky runs in 8 to 11 bands, yielding in some places as much as 2 tons to the yard, but distributed in a thickness of shales varying from 6 to 8 yards.

Bivalves (*Anthracomya*) of several species, and the fish-teeth *Diplodus minutus,* may be found in this measure.

The *New Mine* is poor at Lane end, and but 10 inches at Silverdale. At Longton its shales contain fish remains in great number, forming a regular stratum; they comprise *Holoptychius, Onchus, Gyracanthus, Ctenacanthus, Cladodus, Pleuracanthus, Ctenoptychius, Diplodus, Orthacanthus, Petalodus, Pleurodus,* and *Helodus.*

The *Little Mine* and *Brown Stone* of the western side occur in the same portion of the measures as the *Hanbury* and the *New Ironstone Measures* of Lane End. They are beds capable of producing generally 10 to 12 cwt. to the yard. Fish remains,

mostly of the same genera as mentioned above, also occur in the associated shales.

Prior's Field and *Knowles Ironstone* of Lane End are the leanest in the series. They would appear, from their position between the thick seams of coal called the *Knowles* and the *Ash* or *Rowhurst*, to correspond to the *Gold Mine* ironstone at Silverdale. The Knowles at Lane End is very batty, but turns out 15 cwt. to the yard. In its shales have been found well preserved specimens of the fossil fishes *Palæoniscus* and *Platysomus*, with remains of many other kinds.*

At Golden Hill Colliery the Knowles measures, after an interval of poverty near Shelton, appear to improve, and yield 10 inches of ironstone in four bands, which are 2 feet apart.

In the same part of the series there occurs near Shelton (Pear Tree pit, &c.), but with much irregularity, over the Billy Coal, an ironstone called also the *Billy*, sometimes from 6 to 9 inches thick, of unique character. Whilst all the other stones bear evidence of tranquil deposition and aggregation, and allowing (in the black bands) time for the life and entombment of several successions of mollusca, the Billy ironstone appears to have been formed amid much disturbance, containing rough angular fragments of coal and portions of plants, in such wise as to form occasionally a sort of breccia.

The *Burnwood Ironstone*, resting upon a coal of the same name, varies on the eastern side of the field from 12 inches to 28 inches, but dwindles to 6 inches on the western side.

Below these the ironstones become very scarce and unimportant. One only, quite at the bottom of the series, but not occurring throughout the field with regularity, will be noticed in the description of the Cheadle coal-field.

Considering the great capabilities of the Potteries coal-field, especially in regard to its iron ores, the present production of iron is but small. The following is the return of blast furnaces in 1860:—

Apedale	J. E. Heathcote	4 furnaces.
Biddulph	F. Heath	2 ,,
Lane End	Messrs. Sparrow	3 ,,
Fenton Park	Lawton and Co.	2 ,,
Goldenvale	Williamson Brothers	4 ,,
Clough Hall or Kidsgrove.	Trustees of T. Kinnersley.	4 ,,
Shelton	Earl Granville and Co.	8 ,,
Silverdale	The Silverdale Company.	4 ,,
	Total	31 { of which 25 were in blast.

* Messrs. Garner and Molyneux have within a few years found no less than 38 genera of fishes in this coal-field. Brit. Assoc. Reports, 1859–60.

The quantity of pig iron produced was 146,950 tons. But the amount of iron ore raised in the district is greatly in excess of what is required for smelting into the above quantity of pig, the returns of the North Staffordshire Railway and Trent and Mersey Navigation, showing that 482,729 tons of iron ore, a great part of it calcined, were sent by those modes of conveyance in 1860. The great bulk of it was exported to South Staffordshire, and with it is included a large amount of the Froghall ore from the Cheadle coal-field.

2.—The Wetley and Shafferlong Coal-field.

Brought in and preserved from denudation by a synclinal fold of the lower Carboniferous rocks, a small coal-field extends from Wetley Abbey on the south to Shafferlong, and Deep Hays on the north, with a length of about 3 miles, and a breadth of little more than half a mile. It contains, however, only the two lowermost seams, of very little value in a commercial point of view, although interesting to the naturalist from their association with the peculiar marine fossils which are never found with any of the higher and richer seams.

A few years ago a pit was working at Shafferlong, in which the upper coal at 50 yards deep was 20 to 22 inches thick, rising at an inclination of 7 in 20 towards its out-crop in the direction of Cheddleton. It was of poor quality, but beneath it at a depth of 40 yards was a ten-inch coal of better character. There can be no doubt that these seams correspond exactly to the two bottom coals already mentioned in the Potteries coal-field, and to those which we shall have to notice in the extreme north-eastern part of the district under consideration near Ipstones. The red and brown ore (Froghall ore) found there has been carefully looked for in this isolated little trough, but only indications of it have hitherto been found.

3. The Cheadle Coal-field.

In a breadth from east to west of about 4 miles, and a length from Ipstones to Mobberly of 5 miles, the lower portion of the Coal-measures is exhibited, cropping out on the west, north, and east, and gaining in thickness as it dips under Kingsley to the collieries of Woodhead, and further to the Blake Hall and Delph House pits, on the south of which it is lost under the swelling hills formed of the pebbly beds of the New Red Sandstone.

Even within this limited area, various irregularities of structure in addition to the occurrence of throw faults, have led to much disappointment, especially in the pursuit of the upper thick seam, the "Two-yard" coal, at Blake Hall, and on the hilltop towards Draycott, at which places it would appear to rise again southward, and thus to indicate the occurrence of subordinate basins or troughs, similar to those which have complicated the crop workings in the northern part of this area.

The following section is incomplete at two points, but gives an approximation to the entire series:—

	Yds.	Ft.	In.	
Various measures	65	0	0	Delph-house pits.
Two-yard Coal	2	0	0	
Measures	17	0	0	
Half-yard Coal	0	1	6	
Measures	24	0	0	
Roof of bass with fish-teeth and scales, and *Anthracosia*.				
Yard Coal	0	3	0	
Measures, including 5 to 8 yards of sandstone	19	0	0	
Litley Coal.				
Measures	12	0	0	
Four-foot Coal	0	4	0	
Measures, uncertain	?			
Eaves Coal	0	1	6	
Perhaps indentical with the Two-foot Coal or Cobler Coal of Woodhead	0	2	0	Above the Two-foot and Woodhead seams occur fish-remains in the bass of the roof.
Measures	45	0	0	
Rider Coal	1	0	6	
Measures	35	0	0	
Woodhead Coal, called also Shaws, 2 ft. 7 in. to	0	3	0	
Measures, uncertain	?			
Gibridding or Goblins Hollow Coal, sulphureous	0	3	0	
Measures from boring near Gibridding Wood probably	40	0	0	
Coal Sweet This coal, 8 to 18 inches, is seen at Foxt, Ipstones, and in the Churnet Valley.	0	0	8	Details obtained from the sinkings and borings at Petty field, S.S.W. of Ipstones.
Black Shale	26	2	8	
Coal of Ipstones, Rake Edge, Consal, &c., generally sulphureous. In shale roof are *Orthoceratites*, *Aviculo-pecten Papyraceus*, *Goniatites*	0	2	4	
Underclay (*Marl*) a part of which is often occupied by Gannister	0	5	0	
Shale with bands of Lean Ironstone, and sometimes including a Coal of 8 inches	29	2	0	
Ironstone, Froghall Stone	0	1	10	
Reddish shale	4	2	0	
Upper Millstone Grit Reddish Grit and Conglomerate	25	0	0	
Reddish shale	5	1	0	
Grey Shale with occasional thin beds of Grey Ironstone and veins of Coal	21	0	0	
Coarse grit or sandstone	3	0	0	

In the series of Coal-measures, amounting to about 370 yards in thickness down to the Upper Millstone Grit, bands of argillaceous ironstone occur at intervals, but have hitherto been considered unworkable. Near the base of the series, however, and accidentally discovered by Mr. Bishop, a Cornishman, during a fruitless search for a deeper coal, a very remarkable ironstone has within the last 10 years been largely sought for in the neighbourhood of Froghall, Ipstones, and Consal. Its kindly properties in the smelting furnace have obtained for it a high price, chiefly for exportation to the ironworks of South Staffordshire, and have led to numerous and expensive explorations over an area

of several square miles, throughout which these lower measures are readily accessible. But the results have proved that, although occupying a definite and well-marked position in the series, this so called "Froghall hæmatite" or "hydrate of iron" is subject to variations singularly contrasting with the regularity of some of the neighbouring beds of coal. [v. Anal. XCV.]

The valley of the Churnet, in this part of the river's course is enclosed between thickly wooded, steep, and picturesque banks and hills, which here and there expose to view the Lower Coal-measures, cut down by river action to the rough solid beds of the Upper Millstone Grit. A well marked geological horizon or datum line is afforded by the "sulphur" or "stinking" coal of 2 feet 4 inches to 3 feet, in the roof of which are grouped the interesting marine shells above referred to, which enable us to draw a parallel between this seam, and the lower coals of most of our other coal-fields.

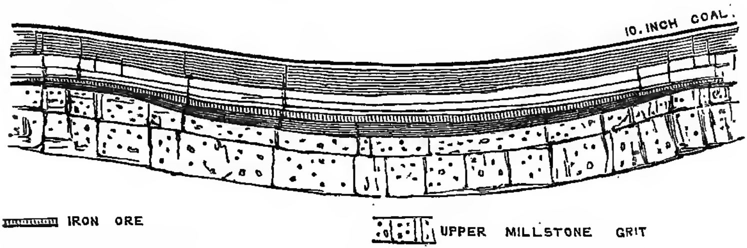
At a depth of from 60 to 114 feet below this bed, and associated with shales which often assume a dark chocolate colour, a band of evenly bedded ironstone, varying from an inch to 22 inches in thickness, lies separated by from 1 to 14 feet of grey or reddish slate clay from the "Rough rock."

The ironstone itself where well developed, as near Belmont, is of a brownish sometimes blackish colour, often striated in the direction of the planes of bedding, 18 to 22 inches thick, and divided by occasional joints lined with calc-spar. On the western bank of the Churnet, where worked by Mr. Bowers, it assumes a bright red colour, and much the appearance of a somewhat earthy hæmatite.

The course of the valley is accompanied by much disturbance among the rocks, both as undulations and fractures or faults, and hence considerable labour has been expended in tracing out this valuable seam. Its position with reference to the underlying grit may be well seen near Consal mill, in the west bank, and in Bishop's level driven under Belmont Wood, where owing to the curvature of the strata the workers have been obliged to drive their gallery through the coarse grit rock to reach the ironstone, which with it dips eastward against the general dip of the strata.

The numerous trial pits and borings which have been undertaken, and the observations of Mr. Binns of Belmont, who has conducted many of the workings, would appear to establish the fact, that the development of the ironstone and even of the shales which lie below it, is coincident with the occurrence of basins or valleys between the hills or saddles of the folded strata; for over these more elevated underground ridges of the Millstone Grit, the ironstone is often represented by a mere trace of reddish ochre or a few inches of inferior stone resting immediately on the

Conglomerate. This character in an exaggerated degree would be expressed by the figure.



Whether this inequality is to be ascribed to an original unevenness in the area of deposition at the time of the subsidence of the sediment which formed the ironstone, or whether it is due to the effect of disturbance subsequent to the deposition, is a somewhat doubtful question.

The ironstone does not seem to make its appearance at the natural basset of the strata at Ipstones, and some of the facts observed by Mr. Binns render it probable that its place is occupied by a kind of black band with black shale, and in other parts even by a bed of impure coal.

Some of the attempts to reach the Froghall stone by borings and sinkings in the underlying strata, where they occupy the surface, have as might be expected been unattended by success, although the occurrence of reddish beds or even thin seams of coal is here, as elsewhere, not unfrequent in the Millstone Grit and its associated shales.

LXXXVII.—Red Shag, Shelton Colliery, Hanley, and Apedale, Newcastle.

(By A. Dick.)

(Nos. 230 and 238 of the Illustrated Catalogue.)

Description.—Clay iron ores. No. 230, colour, dark brown to black; structure, compact; with reddish brown flattened impressions of fossil shells. No. 238 consists of numerous thin layers, varying in colour from light brown to black; structure, compact.

Analysis by Method No. III.

	grs.
Water, hygroscopic and combined:—	
48·67 grs. of ore lost of water at 100° C. - -	0·27
and gave of water at a red heat - - - -	0·71
This water contained a little tarry matter, which makes the number higher than it should be.	
By the action of hydrochloric acid:—	
15·47 grs. of ore gave of—	
Insoluble residue (ignited) - - - ·	0·385
Manganoso-manganic oxide - - -	0·42
Alumina - - - - - -	0·15
Sulphate of lime - - - - -	0·90
Pyrophosphate of magnesia - - - -	0·59

	grs.
3·095 grs. of insoluble residue (ignited) gave of—	
Silica	2·39
Alumina	0·31
Peroxide of iron	0·39
Sulphate of lime	0·10
27·88 grs. of ore gave of—	
Organic matter	2·90
Chloride of potassium	0·09
Phosphoric and sulphuric acids, and bisulphide of iron, 43·29 grs. of ore gave of—	
Pyrophosphate of magnesia	0·52
Sulphate of baryta (from sulphates)	0·06
Sulphate of baryta (from bisulphide of iron)	0·58
27·43 grs. of ore gave of carbonic acid	8·405

Iron by standard solution of bichromate of potash:

Standard: 1 gr. of iron = 8·44 cub. cent. of solution.

	Weight of ore.	Cub. cent. of solution.	Per cent. iron.
I.	8·62	26·4	36·24
II.	8·615	26·0	35·74

Nearly all the iron exists as protoxide, only an extremely small quantity occurring as peroxide.

Results tabulated.

Ore dried at 100° C.

Protoxide of iron	46·53
Protoxide of manganese	2·54
Alumina	0·97
Lime	2·41
Magnesia	1·39
Carbonic acid	30·77
Phosphoric acid	0·69
Sulphuric acid	0·04
Bisulphide of iron	0·34
Water	1·47
Organic matter	10·46
Ignited insoluble residue	2·27
	99·88

Ignited insoluble residue.

Silica	1·93
Alumina	0·25
Peroxide of iron	0·05
Lime	0·03
Potash	0·20
	2·46
Iron, total amount	36·39

No metal precipitable by sulphuretted hydrogen from the hydrochloric acid solution of 780 grains was detected.

LXXXVIII.—Gutter Mine, Shelton Colliery, Hanley.

(By J. Spiller.)

(No. 231 of the Illustrated Catalogue.)

Description.—The ore is composed of alternate layers of clay ironstone, coaly matter, and fossil shells; the clay ironstone predominating towards the middle of the specimen. It readily cleaves in the direction of the plane of stratification, the shells thus displayed bearing the evidence of compression in a direction perpendicular to the plane of cleavage. A small quantity of zinc blende was found in the ore.

In selecting the sample for analysis a cross section was taken, so as to include all the various layers occurring in the specimen.

Analysis by Method No. III.

	grs.
Water, hygroscopic:—	
43·56 grs. of ore lost of water at 100° C.	0·10
Water, total amount:—	
22·37 grs. of ore gave of water at a red heat	0·22
By the action of hydrochloric acid:—	
21·36 grs. of ore gave of—	
Insoluble residue (ignited)	1·025
Manganoso-manganic oxide	0·65
Alumina	0·05
Sulphate of lime	6·18
Pyrophosphate of magnesia	0·86
The insoluble residue (ignited) gave of—	
Silica	0·67
Alumina	0·24
Peroxide of iron	0·12
Oxalate of lime; Phosphate of magnesia and ammonia	traces
43·56 grs. of ore gave of—	
Organic matter	3·89
Chloride of potassium	trace
Phosphoric and sulphuric acids, and bisulphide of iron:—	
39·51 grs. of ore gave of—	
Pyrophosphate of magnesia	0·535
Sulphate of baryta (from sulphates)	0·14
Sulphate of baryta (from bisulphide of iron	0·53
22·845 grs. of ore gave of carbonic acid	7·43

Iron, by standard solution of bichromate of potash:—

Standard: 1 gr. of iron = 8·45 cub. cent. of solution.

Iron, total amount (soluble in hydrochloric acid):—

	Weight of ore.	Cub. cent. of solution.	Per cent. iron.
I.	9·07	20·8	27·13
II.	11·37	26·0	27·06
Iron in the state of protoxide:—			
III.	12·36	27·8	26·62

Results tabulated.

Protoxide of iron	34·22
Peroxide of iron	0·68
Protoxide of manganese	2·87

Alumina	0·23
Lime	11·91
Magnesia	1·44
Carbonic acid	32·52
Phosphoric acid	0·87
Sulphuric acid	0·12
Bisulphide of iron	0·35
Water, hygroscopic	0·23
Water, combined	0·75
Organic matter	8·93
Ignited insoluble residue	4·57
	99·69

Ignited insoluble residue.

Silica	3·13
Alumina	1·12
Peroxide of iron	0·33
Lime, Magnesia, Potash	traces.
	4·58
Iron, total amount	27·33

Distinct traces of lead and copper were detected in 760 grains of the ore.

LXXXIX.—Red Mine, Apedale.

(By A. Dick.)

(No. 239 of the Illustrated Catalogue.)

Description.—Clay iron ore, consists of thin layers; colour, various shades of dark brown; structure, compact. Minute crystals of galena and zinc-blende occur, very sparingly diffused through the ore.

Analysis by Method No. III.

	grs.
Water, hygroscopic:—	
57·24 grs. of ore lost of water at 100° C.	0·17
The combined water was not determined, owing to the comparatively large quantity of tarry matter evolved when the ore was heated to redness to expel the water.	
By the action of hydrochloric acid:—	
18·52 grs. of ore gave of—	
Insoluble residue (ignited)	0·17
Manganoso-manganic oxide	0·37
Alumina	0·05
Sulphate of lime	1·13
Pyrophosphate of magnesia	0·64

1·205 grs. of insoluble residue (ignited) gave of—		grs.
Silica	-	0·64
Alumina	-	0·56
Peroxide of iron	-	0·10
Sulphate of lime	-	0·12
36·00 grs. of ore gave of—		
Organic matter	-	2·30
Chloride of potassium	-	0·08

Phosphoric and sulphuric acids, and bisulphide of iron:—

44·31 grs. of ore gave of—		
Pyrophosphate of magnesia	-	0·51
Sulphate of baryta (from sulphates)	-	0·09
Sulphate of baryta (from bisulphide of iron)	-	0·51
34·28 grs. of ore gave of carbonic acid	-	11·588

Iron, by standard solution of bichromate of potash:—
Standard: 1 gr. of iron = 8·44 cub. cent. of solution.

Iron, total amount (soluble in hydrochloric acid):—

	Weight of ore.	Cub. cent. of solution.	Per cent. iron.
I.	9·51	31·9	39·75
II.	14·36	48·0	39·58
Iron as protoxide:—			
	11·68	38·8	39·33

Results tabulated.

Ore dried at 100° C.

Protoxide of iron	-	50·73
Peroxide of iron	-	0·45
Protoxide of manganese	-	1·86
Alumina	-	0·26
Lime	-	2·52
Magnesia	-	1·26
Carbonic acid	-	33·89
Phosphoric acid	-	0·73
Sulphuric acid	-	0·08
Bisulphide of iron	-	0·30
Water	-	Undetermined
Organic matter	-	6·41
Ignited insoluble residue	-	0·72
		99·21

Ignited insoluble residue.

Silica	-	0·38
Alumina	-	0·32
Lime	-	0·03
Potash	-	0·14
		0·87

Iron, total amount	-	39·84

No metals precipitable by sulphuretted hydrogen from the hydrochloric acid solution of 680 grains of ore was detected.

XC.—Bassy Mine, Foley Colliery, Longton; Shelton Colliery, Hanley; and Apedale, Newcastle.

(By A. Dick.)

Nos. 220, 232, and 240 of the Illustrated Catalogue.)

Description.—Clay iron ores. No. 220, colour, dark brown, streaked with black; structure, compact. No. 232 consists of thin layers; colour, various shades of light brown. No. 240, colour, reddish brown to brown; it contains minute crystals of zinc-blende.

Analysis by Method No. III.

	grs.
Water, hygroscopic and combined:—	
36·66 grs. of ore lost of water at 100° C.	0·19
and gave of water at a red heat	0·74
By the action of hydrochloric acid:—	
22·03 grs. of ore gave of—	
Insoluble residue (ignited)	0·48
Manganoso-manganic oxide	0·41
Alumina	0·07
Sulphate of lime	1·55
Pyrophosphate of magnesia	1·29
3·72 grs. of insoluble residue (ignited) gave of—	
Silica	2·59
Alumina	0·80
Peroxide of iron	0·56
46·95 grs. of ore gave of—	
Organic matter	2·43
Chloride of potassium	0·04
Phosphoric and sulphuric acids, and bisulphide of iron:—	
39·57 grs. of ore gave of—	
Pyrophosphate of magnesia	0·53
Sulphate of baryta (from sulphates)	0·09
Sulphate of baryta (from bisulphide of iron)	0·58
28·82 grs. of ore gave of carbonic acid	9·21

Iron, by standard solution of bichromate of potash:—

Standard: 1 gr. of iron = 8·44 cub. cent. of solution.

Iron, total amount (soluble in hydrochloric acid):—

	Weight of ore.	Cub. cent. of solution.	Per cent. iron.
I.	7·92	25·9	31·63
II.	12·71	41·6	38·75

Iron as protoxide:—

I.	8·725	25·9	35·15
II.	10·41	31·0	35·27

Results tabulated.

Ore dried at 100° C.

Protoxide of iron	45·53
Peroxide of iron	5·00
Protoxide of manganese	1·74
Alumina	0·32
Lime	2·91
Magnesia	2·13
Carbonic acid	32·12

Phosphoric acid - - - -	0·86
Sulphuric acid - - - -	0·08
Bisulphide of iron - - -	0·37
Water - - - - -	2·29
Organic matter - - - -	5·20
Ignited insoluble residue - -	1·95
	100·50

Ignited insoluble residue.

Silica - - - - -	1·36
Alumina - - - -	0·42
Peroxide of iron - -	0·06
Potash - - - - -	0·05
	1·89
Iron, total amount - - -	39·13

No metal precipitable by sulphuretted hydrogen from the hydrochloric acid solution of 1,180 grains of ore was found.

XCI.—Cannel Mine, Apedale, Newcastle-under-Lyne.

(By J. Spiller.)

(No. 241 of the Illustrated Catalogue.)

Description.—Clay ironstone; colour, dark grey; fracture, sub-conchoidal; structure, compact. The ore is intersected by very thin veins of carbonate of lime.

Analysis by Method No. III.

	grs.
Water, hygroscopic:—	
47·425 grs. of ore lost of water at 100° C. - -	0·17
Water, total amount:—	
38·14 grs. of ore gave of water at a red heat - -	0·41
By the action of hydrochloric acid:—	
19·935 grs. of ore gave of—	
Insoluble residue (ignited) - - - -	2·155
Manganoso-manganic oxide ($Mn_3 O_4$) - -	0·46
Alumina - - - - - - -	0·105
Sulphate of lime - - - - - -	2·45
Pyrophosphate of magnesia - - - -	1·695
The insoluble residue (ignited) gave of—	
Silica - - - - - - -	1·46
Alumina - - - - - - -	0·655
Peroxide of iron - - - - - -	0·04
Sulphate of lime - - - - - -	0·02
Phosphate of magnesia and ammonia - -	trace
47·45 grs. of ore gave of—	
Organic matter - - - - - -	0·375
Chloride of potassium - - - - -	0·07

Phosphoric and sulphuric acids, and bisulphide of iron:—

47·425 grs. of ore gave of—	grs.
Pyrophosphate of magnesia - - -	1·03
Sulphate of baryta from sulphates) - - -	trace
Sulphate of baryta (from bisulphide of iron) -	0·065
27·06 grs. of ore gave of carbonic acid - - -	8·765

Iron, by standard solution of bichromate of potash:—
Standard: 1 gr. of iron = 8·45 cub. cent. of solution.

Iron, total amount (soluble in hydrochloric acid):—

	Weight of ore.	Cub. cent. of solution.	Per cent. iron.
I.	19·445	53·4	32·50
II.	11·005	30·2	32·47

Results tabulated.

Protoxide of iron - - -	41·80
Protoxide of manganese - -	2·16
Alumina - - - -	0·53
Lime - - - - -	5·07
Magnesia - - - -	3·03
Carbonic acid - - - -	32·40
Phosphoric acid - - - -	1·40
Sulphuric acid - - - -	trace
Bisulphide of iron - - -	0·04
Water, hygroscopic - - -	0·36
Water, combined - - -	0·71
Organic matter - - - -	0·79
Ignited insoluble residue - -	10·81
	99·10

Ignited insoluble residue.

Silica - - - - -	7·32
Alumina - - - -	3·28
Peroxide of iron - - -	0·20
Lime - - - - -	0·04
Magnesia - - - -	trace
Potash - - - -	0·09
	10·93

Iron, total amount - - -	32·64

A minute trace of copper was detected in 750 grains of the ore.

XCII.—Pennystone, Shelton Colliery, Hanley.

(By A. Dick.)

(No. 233 of the Illustrated Catalogue.)

Description.—Clay iron ore; colour, brown; structure, compact. It contains crystals of zinc-blende.

Analysis by Method No. III.

Water, hygroscopic and combined:—

	grs.
45·83 grs. of ore lost of water at 100° C. - - -	0·14
and gave of water at a red heat - - -	0·665

By the action of hydrochloric acid:—

17·935 grs. of ore gave of—

	grs.
Insoluble residue (ignited)	1·32
Manganoso-manganic oxide	0·31
Alumina	0·05
Sulphate of lime	0·86
Pyrophosphate of magnesia	1·10

3·88 grs. of insoluble residue (ignited) gave of—

Silica	3·08
Alumina	0·65
Peroxide of iron	0·11

31·56 grs. of ore gave of—

Organic matter	0·93
Chloride of potassium	0·10

Phosphoric and sulphuric acids, and bisulphide of iron:—

33·40 grs. of ore gave of—

Pyrophosphate of magnesia	0·35
Sulphate of baryta (from sulphates)	trace

30·60 grs. of ore gave of—

Sulphate of baryta (from bisulphide of iron)	0·18

33·60 grs. of ore gave of carbonic acid - - - 10·87

Iron, by standard solution of bichromate of potash:—

Standard: 1 gr. of iron=8·44 cub. cent. of solution.

Iron, total amount (soluble in hydrochloric acid):—

	Weight of ore.	Cub. cent. of solution.	Per cent. iron.
I.	12·10	38·7	37·88
II.	8·63	27·8	38·15

Iron, as protoxide:—

I.	9·755	29·5	30·27
II.	8·76	26·6	30·36

Results tabulated.

Ore dried at 100° C.

Protoxide of iron	46·35
Peroxide of iron	3·00
Protoxide of manganese	1·61
Alumina	0·30
Lime	1·93
Magnesia	2·24
Carbonic acid	32·46
Phosphoric acid	0·67
Sulphuric acid	trace.
Bisulphide of iron	0·15
Water	1·43
Organic matter	2·95
Ignited insoluble residue	7·29
	100·38

Ignited insoluble residue.

Silica - - - - -	5·78
Alumina - - - - -	1·22
Peroxide of iron - - - -	0·11
Potash - - - - -	0·18
	7·29

Iron, total amount - - -	38·29

No metal precipitable by sulphuretted hydrogen from the hydrochloric acid solution of 765 grs. of ore was detected.

XCIII.—Deep Mine, Foley Colliery, Longton; Shelton Colliery, Hanley; and Apedale, Newcastle.

(By A. Dick.)

(No. 222, 234, and 249*a*. of the Illustrated Catalogue.)

Description.—Clay iron ores. Nos. 222 and 249*a*, colour, greyish black; structure, compact and homogeneous. The cracks contain greyish white hydrated silicate of alumina and carbonate of lime. No. 234; colour, brown; it contains minute crystals of zinc-blende and copper pyrites.

Analysis by Method No. III.

	grs.
Water, hygroscopic and combined:—	
52·68 grs. of ore lost of water at 100° C. - - -	0·13
and gave of water at a read heat - - -	0·445
By the action of hydrochloric acid:—	
14·69 grs. of ore gave of—	
Insoluble residue (ignited) - - - -	1·38
Manganoso-manganic oxide - - - -	0·47
Alumina - - - - - -	0·06
Sulphate of lime - - - - -	0·54
Pyrophosphate of magnesia - - - -	0·48
The insoluble residue (ignited) gave of—	
Silica - - - - - -	0·93
Alumina, and peroxide of iron. (This was found by standard solution of bichromate of potash to contain 0·34 *per cent.* of peroxide of iron) - - -	0·41
22·31 grs. of ore gave of organic matter - - -	0·26
41·79 grs. of ore gave of chloride of potassium - -	0·15
Phosphoric and sulphuric acids, and bisulphide of iron:—	
47·86 grs. of ore gave of—	
Pyrophosphate of magnesia - - - -	0·66
Sulphate of baryta (from sulphates) - - -	trace
Sulphate of baryta (from bisulphide of iron) - -	0·35

Iron by standard solution of bichromate of potash:—

Standard: 1 gr. of iron=8·45 cub. cent. of solution.

	Weight of ore.	Cub. cent. of solution.	Per cent. iron.
I.	9·75	30·9	37·48
II.	9·745	30·9	37·50

Results tabulated.

Ore dried at 100° C.

Protoxide of iron	48·33
Protoxide of manganese	2·99
Alumina	0·41
Lime	1·52
Magnesia	1·19
Carbonic acid	32·76
Phosphoric acid	0·87
Sulphuric acid	trace
Bisulphide of iron	0·19
Water	0·85
Organic matter	1·17
Ignited insoluble residue	9·28
	99·56

Ignited insoluble residue.

Silica	6·25
Alumina	2·41
Peroxide of iron	0·21
Potash	0·22
	9·09

Iron, total amount	37·83

Extremely minute traces of copper and lead were detected in the hydrochloric acid solution of 1,100 grs. of ore.

XCIV.—Chalky Mine, Foley and Shelton Collieries.

(By A. Dick.)

(Nos. 223, 235, and 244 of the Illustrated Catalogue.)

Description.—Clay iron ores No. 223, colour, dark brown to greyish black; structure, compact; it contains minute crystals of zinc-blende and iron pyrites. No. 235, colour, dark brown; it contains white and yellowish grey thin crystalline veins, chiefly carbonate of lime. No. 244, colour, greyish black; the cracks contain white pulverulent hydrated silicate of alumina, coloured in some places with peroxide of iron; zinc-blende is also present.

Analysis by Methoa No. III.

	grs.
Water, hygroscopic and combined.	
36·70 grs. of ore lost of water at 100° C.	0·05
and gave of water at a red heat	0·365

By the action of hydrochloric acid :—

14·95 grs. of ore gave of—

	grs.
Insoluble residue (ignited) - - - -	0·79
Manganoso-manganic oxide - - - -	0·38
Alumina - - - - - -	0·08
Sulphate of lime - - - - -	0·63
Pyrophosphate of magnesia - - - -	0·45
The insoluble residue (ignited) gave of—	
Silica - - - - - - - -	0·46
Alumina and peroxide of iron. (This was found by standard solution of bichromate of potash to contain 0·23 *per cent.* of peroxide of iron) - - -	0·33
29·43 grs. of ore gave of organic matter - - -	0·36
28·47 grs. of ore gave of chloride of potassium - -	0·12

Phosphoric and sulphuric acids and bisulphide of iron :—

45·38 grs. of ore gave of—

Pyrophosphate of magnesia - - - -	0·80
Sulphate of baryta (from sulphates) - - -	trace
Sulphate of baryta (from bisulphide of iron) - -	0·32
27·81 grs. of ore gave of carbonic acid - - -	9·34

Iron by standard solution of bichromate of potash :—

Standard : 1 gr. of iron=8·45 cub. cent. of solution.

	Weight of ore.	Cub. cent. of solution.	Per cent. iron.
I.	10·14	34·0	39·66
II.	10·26	34·4	39·66

Results tabulated.

Ore dried at 100° C.

Protoxide of iron - - - -	51·07
Protoxide of manganese - - -	2·36
Alumina - - - - -	0·54
Lime - - - - -	1·74
Magnesia - - - - -	1·10
Carbonic acid - - - -	33·63
Phosphoric acid - - - -	1·12
Sulphuric acid - - - -	trace
Bisulphide of iron - - -	0·17
Water - - - - -	0·99
Organic matter - - - -	1·24
Ignited insoluble residue - - -	5·18
	99·14

Ignited insoluble residue.

Silica - - - - -	3·02
Alumina - - - - -	1·93
Peroxide of iron - - - -	0·12
Potash - - - - -	0·28
	5·35

Iron, total amount - - -	39·88

Extremely minute traces of copper and lead were detected in the hydrochloric acid solution of 1,093 grs. of ore.

XCV.—ORE FROM FROGHALL, NEAR CHEADLE.

(BY A. DICK.)

Description.—Calcareous hæmatite; colour, brownish red; structure, compact and homogeneous; a vein of calcareous spar occurs in it.

Analysis chiefly by Method No. I.

Water, hygroscopic and combined:—	grs.
21·10 grs. of ore lost of water at 100° C. - - -	0·05
and gave of water at a red heat - - -	1·00
By the action of hydrochloric acid:—	
11·595 grs. of ore gave of—	
Peroxide of iron containing a trace of silica - -	6·15
Sulphate of lime - - - - -	4·105
Pyrophosphate of magnesia - - - -	1·81
13·79 grs. of ore gave of manganoso-manganic oxide -	0·12
Phosphoric and sulphuric acids, and insoluble residue:—	
36·84 grs. of ore gave of pyrophosphate of magnesia -	0·19
24·26 grs, of ore gave of—	
Sulphate of baryta (from sulphates) - - -	0·21
Organic matter and insoluble residue - -	0·325
Insoluble residue (by igniting the *above*) - -	0·01
28·00 grs. of ore gave of carbonic acid - - -	5·07
Alkalies, none were detected in 30 grs. of ore.	

Results tabulated.

Ore dried at 100° C.

Peroxide of iron - - - -	52·83
Protoxide of manganese - - -	0·81
Lime - - - - -	14·61
Magnesia - - - -	5·70
Carbonic acid - - - -	18·14
Phosphoric acid - - - -	0·32
Sulphuric acid - - - -	0·28
Silica - - - - -	trace
Water - - - - -	4·75
Organic matter - - - -	1·30
Ignited insoluble residue - - -	0·04
	98·78
Iron, total amount - - -	36·98

By passing sulphuretted hydrogen through the hydrochloric acid solution of 450 grs. of ore, and reducing the precipitate before the blowpipe, a minute trace of whitish metal was obtained. It was too small in quantity to be identified.

APPENDIX.

NOTES on the NORTH STAFFORDSHIRE COAL FOSSILS; by J. W. SALTER, Palæontologist.

IN Part III. of these Memoirs on the iron ores an attempt was made to illustrate the palæontology of a single section of the coal-measures: The collections were carefully made by gentlemen resident in the Ebbw Vale district; and the hope was expressed that we might receive the aid of other coal owners and local geologists, for a true history of the fossils of the coal measures derived from collections made from the various distinct beds in each district.

Assistance has been most readily given where we have applied for it, and our own collectors are giving their best attention to the subject in the areas now under survey. For the district of North Staffordshire we have had the advantage of examining the fine series made by Messrs. Garner, Molyneux, and Ward. The shells and plants I have myself determined, and while the fishes will be more specially treated of in a Memoir by Professor Huxley, I have availed myself of lists (kindly supplied to me by Mr. J. Ward of Longton), of the fish known from the various distinct seams;—the distribution of these in the strata being the more particular object I have in view.

I do not think it advisable at present to attempt the complete correlation of these seams with those of Ebbw Vale, but the materials for such correlation are partially given here.

I would only call attention to two points:—

1st. That the fossils of the coal seam called "Stinking coal," evidently represent, as Mr. Smyth has shown, those of the lower coal-measures of Lancashire, and also of the Pennystone of Coalbrookedale, and the "Rosser veins" of South Wales (see Part III., Iron Ores, 221.)

2nd, that there is a marked similarity between two of the upper coal seams in this district and the upper ironstone measures of the Ebbw Vale section. If the fossils of the "Soap vein" and "Three-quarter coal" in the Ebbw Vale section be compared with those of the "Knowles Shale" below the Winghay coal and the Burnwood coal of the North Staffordshire section they will be found to agree pretty closely. The presence of no less than three conspicuous shells (not known elsewhere) in each of these localities, viz.,—*Anthracomya Adamsii*, *A. subcentralis*, and *A. pumila*, shows that there must have been an intimate connection between the two areas, at or about the time of the deposition of the respective seams. I will not attempt at present to draw the parallel closer, but the beautiful collections here catalogued will demand a more minute description at some future time.

In the descending section of the measures I have followed the order given me by Mr. Smyth, but have introduced the "Rag mine" above the "Knowles coal" on the authority of a careful section sent me by Mr. John Ward.

I. UPPER MEASURES.

Silverdale.	Shelton.	
Top Red Mine -	Red Shagstone.	——
Black band -	Gutter coal and iron-stone.	*Anthracomya Phillipsii*, Willmsn.
Red Shag - - -	- -	*Anthracomya Phillipsii*, Willmsn.
Red Mine and coal	- - - -	*Do.*

II. POTTERY COALS.

Measures.	Name.	Locality.
Bassey Mine - -	*Stigmaria*, large.	——
	Cytheropsis - - - -	Shelton, Cobridge.
	Spirorbis carbonarius, Murch. -	Cobridge.
	Anthracomya Phillipsii, Willmsn. -	Do.
	Diplodus gibbosus, Ag.	

Measures.	Name.	Locality.
Peacock coal.	—	—
Spencroft coal.	—	—
Gubbin, ironstone shale	*Anthracomya Phillipsii*, Willmsn.	Fenton Park.
	A. sp.	
	Anthracoptera quadrata, Sow.	
	A. sp.	
	Anthracosia robusta, Sow.	
	A. subconstricta, Sow.	
	A. lateralis, Brown	
	Cytheropsis	
	Megalichthys Hibberti, Ag.	Shelton.
	Platysomus	
	Palæoniscus	
	Diplodus gibbosus, Ag.	
	Ctenacanthus Hybodoides, Eg.	
	Pleuracanthus	
	(A flat lancet-shaped tooth, same as Rag Mine)	
Great Row coal.	—	—
Carb. ironstone.	—	—
Cannel Mine	*Cytheropsis*	Burslem.
	Sanguinolites	Apedale.
Woods Mine bass	*Calamites undulatus*, Brong.	Longton, Fenton.
	Palæoniscus, scales.	
	Megalichthys Hibberti, Ag.	
	Diplodus gibbosus, Ag.	
	D. minutus, Ag.	
	Gyracanthus formosus, Ag.	
	(Lancet shaped tooth, same as the one in the Rag Mine, and Gubbin Mine.)	
Pennystone measure ironstone.	—	—
Deep Mine, ironstone	*Cytheropsis*	Longton.
	Megalichthys Hibberti, Ag.	
	Rhizodus.	
	Palæoniscus, 4 or 5 sp., (new).	
	Platysomus, 2 sp., (1 new).	
	Gyrolepis.	
	Ctenacanthus.	
	Cœlacanthus, 2 species.	
	Holoptychius? (large scales).	
	Gyracanthus formosus, Ag.	
	Diplodus gibbosus, Ag.	
	D. minutus, Ag.	
	Ctenoptychius apicalis, Ag.	
	C. denticulatus, Ag.	
	C. pectinatus, Ag.	
	Helodus simplex, Ag.	
	Pleuracanthus lævissimus, Ag.	
	Neuropteris cordata, Brong.	
	N. sp. with serrated edges.	
Deep Mine coal.	—	—
Chalky Mine, ironstone shale	*Anthracomya Phillipsii*, Willmsn.	
	Megalichthys Hibberti, Ag.	Fenton.
	Diplodus gibbosus, Ag.	
	D. minutus? Ag.	
	Gyrolepis	
Coal 1 ft.	—	—
New Mine ironstone bass	*Sigillaria*	Tipton.
	Anthracomya Adamsii, Salter	Kidsgrove, Newchaple.
	Anthracosia robusta, Sow.	Chesterton.
	A. sp.	Harecastle.
	Anthracoptera	Do.
	Megalichthys Hibberti, Ag.	Longton.

Measures.	Name.	Locality.
New Mine, ironstone bass	*Rhizodus* *Palæoniscus*, scales *Platysomus* *Gyracanthus formosus*, Ag. *Orthacanthus cylindricus*, Ag. *Pleuracanthus* (*Diplodus*) *gibbosus*, Ag.	Longton.
	Holoptychius. *Ctenacanthus.* *Cladodus.* *Ctenoptychius.* *Petalodus.* *Pleurodus.* *Helodus.*	
Hanbury Mine.	——	——
Rag Mine, ironstone shale	*Ulodendron minus*, Lindl. *Lepidodendron obovatum*, Sternb. *Sigillaria* *Calamites cannæformis*, Schl. *Anthracosia subconstricta*, Sow. *Megalichthys Hibberti*, Ag. *Holoptychius* *Rhizodus* (large scales) *Palæoniscus*, scales *Gyrolepis*, sp. „ *Platysomus*, 2 var. *Cœlacanthus* *Ctenoptychius apicalis*, Ag. *C. denticulatus*, Ag. *C. pectinatus*, Ag. *Petalodus* *Archodus* *Helodus simplex*, Ag. *Cladodus* *Orthacanthus cylindricus*, Ag. *Gyracanthus formosus*, Ag. *Ctenacanthus Hybodoides*, Eg. *Pleuracanthus lævissimus*, Ag. *Leptacanthus*	Fenton.
Winghay coal, or (Knowles)	Teeth with numerous cusps, (new) *Neuropteris heterophylla*, Brong.	Shelton. Do.
Brown Mine	*Asterophyllites dubia*, Brong. *Calamites approximatus*, Brong. *Ulodendron majus*, Lindl. *U. minus*, Lindl.	Apedale.
	Anthracomya, small sp.	Harecastle.
	Anthracosia *Megalichthys Hibberti*, Ag. *Rhizodus* *Palæoniscus Egertoni*, Ag. *Platysomus*, 2 sp. *Ctenoptychius apicalis*, Ag. *Orthacanthus cylindricus*, Ag.	Silverdale and Apedale.
Knowles Shale	*Anthracomya subcentralis*, Salter *A. Adamsii*, Salter *A. pumila*, Salter *Anthracoptera Browniana*, Salter *A.* sp. *Anthracosia*, sp. like *A. Gerardii*, Brown *Megalichthys Hibberti*, Ag. *Rhizodus*, 2 or 3 sp. *Palæoniscus*, *Platysomus*, 2 sp. *Gyrolepis*	Fenton, Longton.

Measures.	Name.	Locality.
Knowles Shale	*Cœlacanthus* *Diplodus gibbosus*, Ag. *Ctenoptychius apicalis*, Ag. *C. denticulatus*, Ag. *Helodus simplex*, Ag. *Pleurodus affinis*, Ag. *Cladodus* *Ctenodus* (palate and spines) *Gyracanthus formosus*, Ag. *G. tuberculatus*, Ag. *Ctenacanthus Hybodoides*, Eg. *Orthacanthus cylindricus*, Ag. *Leptacanthus* *Pleuracanthus lævissimus*, Ag. *Rhizodus*.	Fenton, Longton.
Knowles ironstone (Gold Mine, Silverdale)	——	
Black Mine	*Anthracosia robusta*, Sow. *A.* sp. *Anthracomya*, sp.	Kidsgrove.

III. Lower Thick Measures.

Measures.	Name.	Locality.
Billy Coal.	——	
Ash or Rowhurst	*Megalichthys Hibberti*, Ag. *Palæoniscus*, scales. *Cœlacanthus* „ *Platysomus* „ *Diplodus gibbosus*, Ag.	
Bass and ironstone.	——	
Little Mine Coal	*Anthracosia ovalis*, Mart. *A.*, sp. *Anatina*—like shell. *Anthracomya Phillipsii*, Willmsn. *Anthracoptera* (*Avicula*) *modiolaris?* Sow. *Cytheropsis*.	Dividy Lane. Adderley Green.
Burnwood	*Anthracomya Adamsii*, Salter *A.* sp. *Anthracosia*, sp. *Cytheropsis*.	Hanley.
Golden Twist.	——	
Ironstone.	——	
Doctors Mine.	——	
Moss Coal, or 4-foot	*Anthracosia lateralis*, Brown *A. subconstricta*, Sow. *Megalichthys Hibbertt*, Ag. *Diplodus gibbosus*, Ag. *Palæoniscus*, scales. *Cœlacanthus* „ *Rhizodus* „	Longton.
Yard Coal bass	*Megalichthys Hibberti*, Ag. *Diplodus gibbosus*, Ag. *Cœlacanthus*. *Palæoniscus*.	
Ragman Mine.	——	
Birches Coal.	——	
Ten-foot Coal	*Anthracoptera Browniana*, Salter. *A.*, sp. *Anthracosia ovalis*, Mart. *A. aquilina*, Sow. *Anthracomya Phillipsii*, Willmsn.	Hanley.
Bowling Alley.	——	

Measures.	Name.	Locality.
Holly Lane	*Anthracosia robusta*, Sow.	Adderley Green.
	A. ovalis, Mart.	Do.
	A. like *acuta*, Sow.	Do. & Dividy Lane.
	Anthracomya, sp.	Adderley Green.
	Anthracoptera like *A. quadrata*, Sow.	
Sparrow Butts Coal	*A.*, sp.	
	Palæoniscus, scales.	
	Megalichthys, teeth.	
	Anthracosia ovalis, Mart.	Dividy Lane.
	A. lateralis, Brown	
	A. aquilina, Sow.	
	A. acuta, Sow.	
	Anthracoptera quadrata, Sow.	
	A. carinata, Sow.	
	Anthracomya modiolaris, Sow.	
Stinking Coal.	—	
Flatts Mine.	—	
Banbury Mine or Frogs Row.	—	
Cockhead	*Beyrichia arcuata*, Bean.	
	Spirorbis carbonarius, Murch.	
	Megalichthys Hibberti, Ag.	Dividy Lane.
	Ctenacanthus Hybodoides, Ag.	
	Psammodus :	
	Helodus not *H. simplex*, Ag.	
	Pleuracanthus	
	Anthracosia acuta, Sow.	
	A. ovalis, Mart.	
	A. lateralis, Brown	
	A., 2 sp.	Adderley Green.
Sudden Coal.	—	
Bullhurst	Shales with *Aviculopecten papyraceus*, Sow. (Smyth).	
Winpenny.	—	

IV. Lowest Measures.

The Cheadle section gives some of the lower beds, and especially the seam alluded to by Mr. Smyth, p. 278. We have the following in Mr. Ward's collections:—

4-foot Coal	*Goniatites* and *Lingula* in roof (Smyth).	Wetley More.
2-foot Coal	*Anthracomya Phillipsii*, Willmsn.	Portobello, Cheadle.
	Anthracosia	
Woodhead Coal Shale	*Anthracoptera*, sp. more oblique than *A. Browniana*, Salt.	Ladies Well.
	Anthracosia ovalis, Mart.	
Stinking Coal Shale	*Aviculopecten papyraceus*, Sow.	Frogshall.
	Calamites	
	Lepidodendron and *Ulodendron*	
	Goniatites Listeri, Sow.	
	Orthoceras	
	Lingula mytiloides, Sow.	

I also add the contents of one or two mines or seams (for which we have at present no place), because they contain characteristic fossils, viz:—

Harrett's Cross ironstone	*Anthracosia robusta*, Sow.	Kingsley Moor.
Unworked ironstone	*Anthracomya Phillipsii*. Willmsn.	Hartshill.
	Cytheropsis	„ and Newcastle.
(Top of middle measure)		